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International Geological Congress

Eighteenth Session—Great Britain, 1948

ABSTRACT

The scientific proceedings of the Eighteenth Session of the International Geological Congress included twelve series of Sectional Meetings, open meetings of the Association of African Geological Surveys, and of the International Paleontological Union, and special discussions on the Geology and Mineralogy of Clays. Summaries of these Sectional and other meetings, prepared by their officers, are published in advance in the full Report of the Session.

PROCEEDINGS OF THE SECTIONAL MEETINGS

Introduction

By A. J. BUTLER

TWELVE separate series of Sectional Meetings were arranged during the Eighteenth Session :—

	Section.	*First Chairman.*	*Secretary.*
A.	Problems of Geochemistry	C. E. Tilley	S. R. Nockolds
B.	Metasomatic Processes in Metamorphism	A. Holmes	Doris Reynolds
C.	Rhythm in Sedimentation	W. G. Fearnsides	P. Allen
D.	The Geological Results of Applied Geophysics	W. F. P. McLintock	J. McG. Bruckshaw
E.	The Geology of Petroleum	V. C. Illing	G. D. Hobson
F.	The Geology, Paragenesis and Reserves of the Ores of Lead and Zinc	W. R. Jones	K. C. Dunham
G.	The Geology of Sea and Ocean Floors	O. T. Jones	W. B. Harland
H.	The Pliocene-Pleistocene Boundary	W. B. R. King	K. P. Oakley
J.	Faunal and Floral Facies and Zonal Correlation	A. E. Trueman	H. Dighton Thomas
K.	The Correlation of Continental Vertebrate-bearing Rocks	D. M. S. Watson	W. E. Swinton
L.	Earth Movements and Organic Evolution	H. L. Hawkins	F. Hodson
M.	Other Subjects	E. B. Bailey	R. M. Shackleton

The Chairman opened the proceedings of his Section, and was afterwards at liberty to invite other geologists to succeed him in the

Chair. The Secretary recorded the whole of the proceedings of the Section.

In addition to the Sectional Meetings proper there were three other series of open meetings, arranged by :—

The Association of African Geological Surveys: President, F. Dixey; Secretary, F. Blondel.

The International Paleontological Union: President, P. E. Pruvost; Secretary, B. F. Howell; Secretary of the British Committee, C. J. Stubblefield.

The Clay Minerals Group of the Mineralogical Society: Chairman, G. W. Brindley; Secretary, D. M. C. MacEwan.

The following pages contain summaries of these Sectional and other meetings, prepared by their officers. The country of each contributor from abroad is given in brackets after the first mention of his name; except in the cases of the Chairmen, personal titles are omitted.

An account of the general proceedings of the Session and of the main conclusions of the Council was given in the last number of the *Geological Magazine* (A. J. Butler, *Geol. Mag.*, 1948, lxxxv, No. 6, 361–5).

Section A: Problems of Geochemistry

By S. R. Nockolds

There were three meetings of Section A, Problems of Geochemistry, during the course of the Congress. The first of these opened with Professor C. E. Tilley in the Chair, and he was succeeded half-way through by Professor P. Niggli (Switzerland).

The first paper was one by N. L. Bowen (U.S.A.) and O. F. Tuttle (U.S.A.), on "Serpentine and talc equilibria", and gave the results of experimental investigations of the equilibrium relations of talc and serpentine with the anhydrous phases forsterite, enstatite, periclase, and silica, at pressures of water vapour up to 30,000 pounds per square inch and temperatures up to 900° C. No liquid phase is formed in any composition up to the highest temperatures and pressures at which the investigations were carried out. The following paper by J. M. C. Neiva (Portugal), on "Serpentines and serpentinization", outlined a detailed classification of the essential serpentinous minerals, and the author suggested the possibility of explaining hypogene serpentinization in the solid condition by the diffusion of H^+ ions through the crystal lattices during the final stages of differentiation of the peridotitic magma.

H. von Eckermann (Sweden) dealt with "The distribution of barium

in the alkaline rocks and fenites of Alnö Island ". The data available show that there was considerable migration of Ba ions from the intrusive liquids into the metasomatically altered wall rock, and that Ba is concentrated in the residual solutions as exemplified by the leucocratic and carbonatitic rocks rich in potash.

A paper which gave rise to considerable discussion was that by E. Saether (Norway), " On the genesis of peralkaline rock provinces ". The author holds the view that peralkaline magmas are generated by diffusion processes in a magma mass of very great vertical extension. In such a mass, the volatiles and ions such as Na^+, K^+, Ca^{++}, Ba^{++} will be enriched at the top of the chamber and hence a peralkaline magma, rich in CO_2 and other volatiles, will be formed.

C. Oftedahl (Norway) considered " Special features of the Oslo igneous feldspars ". Detailed investigation shows that plagioclase, previously unidentified owing to the fact that the albite lamellae are exceptionally thin and can be seen only in sections perpendicular to (010), forms an important constituent of such rocks as larvikite, lardalite, and some nordmarkites. The alkali feldspars are transitional from cryptoperthite to microperthite and the cryptoperthites were found to belong to the " orthoclase-microperthite series " of Ed. Spencer.

The final paper was one by E. S. Larsen (U.S.A.) and W. M. Draisin (U.S.A.), " Composition of the minerals in the rocks of the Southern California batholith." The batholith contains rocks ranging from calcic gabbro to granite and nearly all the analyses lie near smooth variation curves, indicating a close consanguinity. It was found that the ratio $\frac{FeO}{FeO + MgO}$ is about the same for any rock and for all the mafic minerals in that rock, and increases along a smooth curve from 0·36 in the calcic gabbros to 0·85 in the granites. The anorthite content of the plagioclase changes regularly with the composition of the rock. The minerals of these coarse-grained rocks were compared with the phenocrysts of the volcanic rocks of the San Juan region of Colorado, where no such systematic changes occur.

Dr. N. L. Bowen was in the Chair for the first half of the second meeting and was followed by Professor W. Wahl (Finland). P. Niggli opened the proceedings with a paper on " The presentation of geochemical data ". After dealing with the various methods of presentation and pointing out that a certain uniformity was desirable, the author gave examples of the advantages of using atomic and molecular values, rather than weight-percentage values.

W. Nieuwenkamp (Netherlands), in a paper entitled " The geochemistry of sodium ", considered certain aspects of the geochemistry of that metal from a quantitative point of view, while R. W. van

Bemmelen (Netherlands), in "Cosmogony and geochemistry", attempted to describe geological evolution as a link in cosmic evolution. In stellar evolution the course of the process is determined by nuclear reactions; in the development of planets the reactions between the outer electronic shells play a dominant role. Deductive reasoning about the origin of the planetary system leads to conclusions about the character and course of the endogenic process. The source of endogenic forces is the energy liberated by irreversible, physico-chemical chain-reactions.

In a paper "On geochemical types of orogenic zones", Y. A. Bilibin (U.S.S.R.) distinguished internal and external zones of metallogenic belts. The internal zones are characterized by metals of the Fe group, the Pt group, Cu, Mo, Hg. The external zones are characterized by Sn, W, Bi, Pb, Zn. The two zones differ also in the nature of their mineralizers and in their rock types.

D. S. Korzhinsky (U.S.S.R.), dealing with "Phase rule and geochemical mobility of elements", showed that by applying the phase rule to rocks it could be established that some components under given conditions are "perfectly mobile" (their concentrations in solution being independent factors), whereas others are "inert" (their concentrations in solution being functions of their content in the rock). The geochemical mobility of elements and oxides depends on the activity of solutions, temperature, and depth, and three series of decreasing mobility were given, (*a*) for high temperature processes at depth, (*b*) for high temperature processes near the surface, (*c*) for low temperature processes near the surface.

Finally, J. P. Marble (U.S.A.), gave a paper on "Some applications of autoradiography", in which he showed that a prepared surface of a radioactive mineral, when placed in direct contact with a photographic plate for an optimum time, will yield valuable information as to the relative radioactive content of different parts of the specimen. Moreover, by exposing for the same length of time chips of an unknown mineral with others whose U + Th content is known, a semi-quantitative estimate of the U + Th content of the unknown can be rapidly made.

At the final meeting, Professor P. Geijer (Sweden) and Professor D. S. Korzhinsky occupied the Chair. W. Wahl presented a paper on "The vertical circulation of matter in the earth's crust", dealing with the vertical circulation brought about by warping down of portions of the crust whereby palingenic granite magma is formed at certain depths by differential remelting of the crust. This magma, being less dense than the remaining femic material of the partially molten rock, will rise and form an upper "sial" layer, the remaining femic material forming the upper portion of the "sima" layer. The sodium-rich

portions of the plagioclase feldspars of diorites and gabbros will also melt at certain depths, together with the kaliophilite constituent of broken up mica, forming foyaitic magma. Where the entire rock ground is remelted, the granodioritic magmas of the orogenic belts are obtained.

L. R. Wager and R. L. Mitchell considered "The distribution of Cr, V, Ni, Co, and Cu during the fractional crystallization of a basic magma". The amounts of these elements had been determined spectrographically in the rocks of the Skaergaard intrusion and in the plagioclase feldspars, pyroxenes, olivine and iron ore in the rocks.

J. S. Brown (U.S.A.) questioned the validity of the hydrothermal origin of ores in a paper entitled "An alternative to the hydrothermal theory of ore genesis". Paragenesis is related to specific gravity in such a way as to indicate gravity stratification in the source magma. Zoning is similarly related to volatility and this implies that the major method of transfer was as vapour. Support for the theory is found in the principles of blast furnace smelting with the differentiation of dissimilar substances into layers of slag, matte, and speiss. The heavy sulphide layers were shown to be analogous to probable sulphide ore magmas. An English abstract was given of a paper by C. Andreatta (Italy) "Sull'alterabilità dei minerali delle rocce", in which he considered some aspects of the alterations of rock-forming minerals, and G. M. Cardoso (Spain), in association with I. P. Pondal (Spain), closed the proceedings with a paper on the chemistry and mineralogy of a porphyritic biotite granite and its associated rock types, entitled "Quimismo de algunos granitos de Pontevedra (España)".

Section B. Metasomatic Processes in Metamorphism

By Doris L. Reynolds

Professor A. Holmes was Chairman at the opening of the meetings of the Section; subsequently Professor H. H. Read, Professor E. Wegmann (Switzerland), Professor E. S. Larsen (U.S.A.), Professor P. Eskola (Finland), and Professor H. von Eckermann (Sweden), were invited to the Chair.

Many of the papers presented to Section B, on metasomatic processes in metamorphism, were concerned with the phenomena of granitization, one of the most actively discussed geological topics of the present time. Whereas all the participants were agreed that there is good evidence that various types of rocks have been granitized, there was a sharp division of opinion as to the way in which this has been brought about. Some geologists, adhering to the view advanced by the French school in the last century, considered that metasomatic replacements

resulting in granitization are to be attributed to the action of granite magma, visualized as having been injected along easily penetrable divisional planes within the rocks concerned. The alternative explanation, for which evidence was presented by several geologists, is that granitization is the result of solid diffusion.

P. Eskola considered that the fact that some granites, having all the hall-marks of a metasomatic origin, are identical with others that he regarded as of magmatic origin is strong evidence for the notion that granite magma has been the source of the added materials in all cases. He selected granophyre as a typical granitic rock that he thought all geologists would agree to be of magmatic origin, and pointed out that the metasomatic granites in the Pre-Cambrian of Finland are chemically similar. Eskola then indicated, for common rock types, the constituents that have to be added to bring about granitization, and stressed the fact that other constituents have to be subtracted. Thus, for example, when argillaceous rocks are granitized the chemical change implies addition of SiO_2 and K_2O and subtraction of FeO and MgO. Eskola thought it impossible to say what has become of such displaced constituents, the removal of which he supposed to be controlled by the law of mass action.

In a study of the origin of the Sörmland gneisses of Central Sweden, N. H. Magnusson (Sweden) concluded that leptites, slates, and granites have been transformed to gneiss as a result of introduction of Al, Fe, and Mg, with removal of Si, Ca, and alkalies. He ascribed the change to the action of granitic emanations and solutions derived from deeper levels as a result of palingenesis. In doing so he claimed for granitic solutions an effect diametrically opposed to that which Eskola supposed to obtain.

Doubt was thrown on the magmatic origin of granophyres in general, an assumption that formed Eskola's starting point, by Doris L. Reynolds, who demonstrated with lantern slides the detailed transition of Caledonian granodiorite to Tertiary granophyre on Slieve Gullion, in Co. Armagh, N. Ireland. This transition has clearly taken place in the solid state, the transformation having resulted from introduction of K and Si, with concomitant removal of Fe, Mg, and Ca.

H. G. Backlund (Sweden), in a paper presented *in absentia*, showed that the Swedish granites of Revsund, Filipstad, and Uppsala, all conforming with the chemical criteria generally adopted for the recognition of supposedly magmatic granites, have resulted from solid diffusion. His demonstration, depending on structural, textural, petrographic, and geochemical evidence, leads to the conclusion that the mega-porphyritic granites are the transformation products of sediments of fairly equal competence exhibiting harmonious isoclinal folding, whilst the even-grained granites represent sediments of varying

competence with crumpling and disorderly folding. Consequent on granitization Fe, Mg, etc., were displaced and became fixed within limestones and basaltic rocks intercalated in the geosynclinal sediments undergoing granitization, and in skarn of basic front type. Geochemical investigations have revealed the fact that the trace elements in ores associated with the granites and skarns exhibit highly variable proportions incompatible with any supposition that the ores are a consequence of magmatic differentiation. H. G. Backlund explained the ores as the result of enrichment, at several different periods, of original poorer sedimentary ore deposits. He correlated these enrichments with expulsions of excess materials from sedimentary rocks (probably biochemical) that are now granitized ; on this view the variable proportions of trace elements within the ore minerals reflect the geochemical discontinuities that characterized these sediments.

H. G. Backlund's paper reminded E. S. Larsen of a granite exposed in a tunnel near Ware, Massachusetts. In the tunnel, gently dipping mica-schists are cut by a granite mass over a mile wide. Near the contacts with the granite the schist contains lenses of granite, several inches thick, that extend parallel to the bedding and schistosity. The schistosity has not been distorted and bent as it must have been if the granite had been injected. The granite-schist contact is sharp and cuts across the schistosity, but the granite shows a distinct though faint layering parallel to that of the schists.

E. Wegmann said that from a structural point of view granite massifs are of two types, those formed by transformation *in situ*, and diapirs formed by mobilization. He stressed the fact that intrusion is a displacement, and that study of intrusions is essentially a study of differential mobility for which modern tectonic methods are necessary. Even when movement has been proved, Wegmann said, it then becomes necessary to discriminate between flow of material in a melted condition and flowage of material comparable to that of glacier ice. He further said that Goldschmidt's geochemical work demonstrated the mobility of certain materials, but his results lacked co-ordination with geological events. Careful study of the stratigraphic, tectonic, and kinematic setting reveals the phenomena of transformation in terms of a tectonic geochemistry.

D. S. Korzhinsky (U.S.S.R.) discussed metasomatic diffusion zoning in fissures and metasomatic filtration zoning within rock masses. In principle he considered that diffusion resulting in such zoning could take place either through aqueous pore solutions or through a solid crystalline medium. Study of granite-gneiss contacts, however, especially with reference to reaction zones between adjacent rocks, led him to the conclusion that metasomatic phenomena in

metamorphism occur only in rocks which are soaked by ascending solutions.

M. E. Roubault (France) proposed that, at the next meeting of the International Congress, the study of veins associated with granite should receive particular attention; if veins have really been filled by magmatic agencies then it should be possible to fit their walls together without leaving any gaps. He said that whereas it is certain that there are granites of metasomatic origin, it is still questionable whether granite of magmatic origin exists or not.

L. T. Nel (S. Africa) exhibited a series of coloured lantern slides of manuscript geological sheets, with the object of drawing the attention of geologists to extensive exposures of granitized rocks in Namaqualand, South Africa. He said that in Namaqualand there are highly metamorphosed sedimentary rocks with associated lavas and dolerites which appear to provide a gradual transition from stratified rocks into gneisses and granite. He thought that this area could provide much evidence of the kind needed for a satisfactory solution of the problem of the origin of granites.

Other important contributions presented to Section B, describing metasomatic phenomena dependent on introduction of materials similar to those lost during granitization, were presented by I. Campbell (U.S.A.) and A. R. Alderman (Australia). Campbell described a series of meta-sediments, possibly including some meta-volcanic rocks, within which a stock-like mass of tonalite has been emplaced. The dominant rock within the meta-sediments is composed of dolomite and brucite, so that it contains too high a ratio of MgO to CaO to be explained as a dolomitic sediment that has recrystallized without change of composition. Obviously, MgO has been added from an external source, and Campbell discussed the various possibilities.

Alderman described some sillimanite and kyanite rocks from Australia that have resulted from alumina metasomatism.

An important paper by H. von Eckermann showed that nepheline-syenite at Alnö, which had previously been thought to represent a magma, is in actual fact nephelinized gneiss. He also demonstrated that carbonate rocks associated with the nepheline-syenite, which have previously been regarded as limestone xenoliths, occupy the cone-sheet fractures of a volcanic breccia.

Section C. Rhythm in Sedimentation

By P. Allen

"Rhythm," as used by geologists in Section C, is a general term describing the repetition of sedimentary types in space or time. The

repetition is observed by measuring vertical sections such as quarry faces, bore-holes, and cliffs, and by detailed mapping. It may be simply *banding* (as 1212121 . . .), or *cyclic* (as 123212321 . . .), or *pulsatory* (as 123, 123, . . .), and intermediate forms of rhythm are known to occur. The discussions were confined to cyclic and pulsatory rhythms, and included rocks ranging from Pre-Cambrian to Recent.

A great variety of possible causes (compaction, subsidence, climatic variation, change in topography and constitution of contributory land-areas, etc.) was debated. As the work of the Section proceeded, it became increasingly clear that (1) the same general types of rhythmic lithology have very wide distributions (e.g. the Upper Carboniferous cycles and pulses of North America and Europe) ; (2) the underlying causes may vary from place to place and time to time ; (3) similar lithological sequences do not necessarily imply similar causes.

The first meeting (Chairmen : Professor W. G. Fearnsides and Professor R. C. Moore (U.S.A.)) was devoted to Palaeozoic cycles and pulses. R. C. Moore, H. R. Wanless (U.S.A.) and B. Willard (U.S.A.) spoke from experience in the United States, S. van der Heide (Netherlands) from experience in Holland and Anatolia, and K. C. Dunham from the northern Pennines of England. The emphasis placed by van der Heide on compaction (with subsidence) as an important factor in causing rhythm stimulated a valuable discussion. A comparison between certain cycles of northern England (Dunham) and those of America (Moore, Wanless, Willard) resulted in an attempt to find agreement over the best stratigraphical level at which the beginning of a cyclothem should be placed. This failed, partly owing to some workers' preferring a rigid genetic classification while others (field geologists) preferred the base of a cyclothem always to be a mappable boundary, and partly because many workers saw no advantage in such standardization anyway.

The second meeting (Chairman : Professor W. G. Fearnsides) was devoted to Mesozoic and Tertiary rhythms. G. Troedsson (Sweden) described the Rhaetic-Liassic beds of Sweden, A. Vatan (France) the Cretaceous and Tertiary sedimentation of the Aquitaine basin, A. Bersier (Switzerland) the mollasse of the alpine fore-deep, and E. Wegmann (Switzerland) discussed the rhythmic effects of climate as opposed to earth-movements.

The contribution of A. Vatan was unique in that it dealt principally with rhythms in detrital composition, and that of A. Bersier stirrèd up a lively debate. During the latter, A. E. Lombard (Belgium) outlined a new explanation of certain types of cycle and pulse.

Section D. The Geological Results of Applied Geophysics

By J. McG. Bruckshaw

Fifteen papers were presented at the three meetings of this section, each meeting containing papers on related subjects. Appropriately, instruments and new techniques were not covered, the application of standard methods to special geological problems being the main theme. The section was opened by the Chairman, Dr. W. F. P. McLintock, but subsequently the Chair was occupied in succession by Dr. L. Migaux (France), Dr. A. van Weelden (Netherlands), Dr. J. Renner (Hungary), and Dr. J. Phemister.

Four of the papers in the first session, on electrical surveys, were devoted to resistivity surveys. I. de Magnée (Belgium) summarized a successful application which delineated a diamond-bearing pipe in the Belgian Congo, its presence but not its position being known from geological considerations. The important problem of water location was treated by J. J. Breusse (France), and G. Castany (Tunisia). The former was able to distinguish between fresh and saline waters on the Dakar Peninsula, while the latter described the location of buried faults in Tunis, the faults controlling locally the accumulation of water. The last resistivity survey, discussed by L. S. Palmer, was to determine the chalk contours below recent deposits in Holderness, and it illustrated some of the interpretational difficulties arising from the variability of geological formations. In his description of a potential drop ratio survey, A. A. T. Metzger (Finland) suggested a modification of the normal method of plotting the results, a modification which, in the example discussed, appeared to have diagnostic value. Considerable interest was shown in the telluric method discussed by L. Migaux (France), who demonstrated in two cases that this method, coupled with resistivity observations, gave a clearer picture of underground conditions than the gravity method.

The seismic investigations ranged from deductions made from near earthquakes, through normal reflection methods to small-scale studies. F. Montandon (Switzerland) illustrated, in the North-West Alps, the close relation between zones of frequent and intense shocks and regions with numerous and large faults and dislocations, the latter showing previous seismic activity. The fortunate relation between the focus of the earthquake of 25th January, 1946, in Switzerland, and four recording stations, allowed N. Oulianoff (Switzerland) to examine the crustal structure there and to suggest a tectonic relationship between the massifs of Mont Blanc and the Vosges, and those of the Aar and the Black Forest. Seismic reflection methods, used by O. Heermann (Germany) in the N.W. German Permian Basin, have resulted in a better appreciation of the growth and structure of saltdomes there

while, on a still smaller scale, O. Vecchia (Italy) described many successful dam site surveys in Italy, using the refraction technique.

V. E. Barnes (U.S.A.) described the first successful gravity survey leading to the discovery of a lead-zinc deposit. The small anomalies here contrasted with those in Wales and the Borders discussed by H. I. S. Thirlaway, and which showed the lack of isostatic compensation in the Mid-Wales Plateau and the existence of large faults near Worcester. An interesting torsion balance survey over the Warburton Fault, Cheshire, concluded the contributions on this aspect. The two final papers involved the co-ordinated interpretation of several surveys in the same area. The area between the Saone and the Rhone was discussed by J. Goguel (France) in the light of gravity, telluric, and resistivity surveys, while A. Bentz (Germany) described the magnetic, gravity, and seismic refraction maps of N.W. Germany and their geological significance.

The proceedings illustrated the wide range of geological problems amenable to solution by these methods, if due attention is given to the geological conditions, and further revealed a growing tendency to employ them to assist in the elucidation of both academic and commercial problems.

Section E. The Geology of Petroleum

By G. D. Hobson

The three meetings of Section E were conducted under the general Chairmanship of Professor V. C. Illing, but during part of the first Mr. P. Evans occupied the Chair, while Dr. G. M. Lees officiated during the second, and Dr. H. G. Kugler (Trinidad) and Mr. A. R. Denison (U.S.A.) during the last meeting.

The first paper at the Thursday morning meeting was read by L. Barrabé (France). In " Quelques considérations sur les gisements de pétrole du Sud de la France ", he outlined the history of the search for oil in southern France, and briefly described the structure and stratigraphical history of the Aquitaine basin, the Petites-Pyrénées, and the Languedoc basin. In recent years the search has resulted in the discovery of substantial gas production and a small output of oil, in addition to revealing some shows of oil. Possible source rocks range in age from basal Oligocene to Lower Permian, the Middle and Upper Cretaceous and the Lower Permian being the most likely sources. Geophysical and geological work and drilling have thrown new light on the stratigraphy and tectonics of this region. There is evidence of the former existence of an ancient cordillera north of the Pyrenean front.

In August, 1947, a well near the axis of the Anadarko basin in Oklahoma was abandoned at a depth of 17,823 feet. In speaking on the "Significance of the world's deepest well bore", R. R. Wheeler (U.S.A.) remarked that there were some evidences of oil at 8,200 feet, but a drillstem test was inconclusive. 3,500 feet of Deese beds were found resting unconformably on Atoka limestones and sandstones, affording confirmatory evidence that the Arbuckle-Wichita orogenic movements were initiated in early Pennsylvanian times and culminated in post-Atoka pre-Des Moines time, i.e. at a later date than has long been assumed by Mid-Continent geologists. A lateral shift of the structural axis at depth was indicated, a phenomenon which was considered in general terms in the following paper by H. R. Tainsh (Burma) on "An aid to the forecasting of underground structures". Tainsh made a plea for the formation of a collection of geological cross-sections carefully compiled from surface and subsurface data on structures showing strong dips, because these would probably be of value in guiding deep exploration on previously unexplored structures, and would provide material for the detailed analysis of folding, especially in incompetent beds.

W. B. Wilson (U.S.A.), who gave a paper on "Some aspects of petroleum migration", contended that a flattening of the dip of the formations was in itself not sufficient to give a commercial oil accumulation. He believed that oil migrated at an early date. At times this migration may have been before structural traps had been formed, although stratigraphic traps might be available.

The second meeting consisted of a series of papers on the Middle East and near-by areas. G. M. Lees outlined the principal features of the main area in a paper on "Some structural and stratigraphic aspects of the oilfields of the Middle East". Sediments from Cambrian to the Tertiary showing no marked discordance are present in this region. From the Permian onwards sedimentation was fairly continuous and dominantly calcareous. In detail the rocks change towards the Arabian foreland, the chief difference between this and the Iranian area being the absence of a great thickness of Tertiary in the former. Strong structures occur in the Iran and Iraq oilfield areas, and to the north-east, but towards the Arabian shield dips are generally less than 3°–4°.

In Iran and Iraq the first big barrier to upward migration of oil is the Lower Fars series, and oil production has been obtained from the immediately underlying Asmari and Main Limestone series, respectively, in these two countries. Many possibilities exist with regard to source rocks—Asmari, Eocene, Upper, Middle, and Lower Cretaceous, Jurassic, Triassic, and even Cambrian rocks—and there are vertical fissure connections with the reservoir rocks. Live oil noted in some Cretaceous cores may be in process of upward migration.

Towards the Arabian foreland there are considerable developments of anhydrites which can act as cap-rocks. The source of the oil is not settled, but there is oil in the Jurassic and Cretaceous.

In the Iran oilfield area are anticlines as much as 200–250 miles long. The incompetence of the Fars series has given rise to extreme disharmony between the surface and deeper structures. Surface synclines have been found over subsurface anticlines.

The salt dome structures of Iran are subsidiary to the main folds amongst which they are found. There are dead salt plugs which have apparently exhausted the parent salt bed, and active plugs which seem to be in a kind of hydrostatic equilibrium with the enclosing sediments.

In a paper on "The Asmari Limestone of south-west Iran", A. N. Thomas (Iran) discussed lateral variation and correlation in the Asmari. He concluded that in the wide sense the term Asmari Limestone formation should include the underlying Brissopsis Beds, the Kalhur Limestone of the Khanaquin district, and probably also the Khamir Limestone. Some parts of the Asmari were deposited under conditions believed to be favourable for oil formation, and it was considered that the Asmari oil might therefore be indigenous.

The following paper, by F. R. S. Henson, was on "The stratigraphy of the Main Producing Limestone of the Kirkuk oilfield". A description of the general pattern of typical Middle East reef complexes was given, and the petrological and physical characteristics of the main parts, together with the environment of formation, were described. A stratigraphic break immediately above the reservoir over much of the Kirkuk structure was considered to afford evidence on the time of oil accumulation and on the age of the oil source rock.

The structural complexities of the Iranian oilfield belt were the subject of a paper by C. A. E. O'Brien on "Tectonic problems of the oilfield belt of south-west Iran". O'Brien considers that the salt-laden Lower Fars Series constitutes a mobile group between competent pre-Fars beds and incompetent Fars-Bakhtiari deposits, and is largely responsible for the extraordinary structural differences between the Asmari limestone and the surface beds. Orogenic movements are believed to have formed great anticlinal structures in competent pre-Fars beds, and the overlying plastic series is thought to have reacted in close conformity with the laws ofhydrostatics, leading to the flow of salt from high pressure areas over rising anticlines into adjacent synclinal areas.

E. R. Gee's paper on "Petroleum geology in Pakistan", presented by H. Crookshank, dealt chiefly with Western Pakistan, and summarized the geological history and stratigraphy. A brief account of the oil exploration and exploitation was included.

In a paper on "The stratigraphy of the Alexandretta Gulf Basin",

C. E. Tasman (Turkey) noted that in the basin and adjacent uplands were some 30,000 feet of sediments, ranging in age from Silurian to Quaternary. Quartzites and dolomites topped by Carboniferous shales represented the Palaeozoic, whilst the Mesozoic was marked principally by limestones. The Tertiary, which accounted for two-thirds of the total sequence, and was mostly Miocene, contained shales, sandstones, and conglomerates of neritic and continental origin.

The foregoing group of papers provoked considerable discussion, in the course of which J. L. Rich (U.S.A.) expressed doubt about the feasibility of the mechanism involved in the tectogene concept. L. G. Weeks (U.S.A.) contended that there were many prolific oil-bearing basins in which bituminous oil-smelling strata were absent or of minor importance, while other basins had large amounts of highly bituminous strata with no oil. He believed that source and reservoir rocks could be contemporaneous, and that the presence of a stratigraphic break immediately above the reservoir rock was not always conclusive evidence against such a possibility. W. L. F. Nuttall drew attention to a break and reef conditions in the " Golden Lane " of Mexico comparable with those of Kirkuk.

The last meeting began with a paper on " The oilfield of Ganso Azul, Peruvian Amazonas region ", by A. Heim (Switzerland), and was followed by one on " Some outlines on the tectonics of the Upper Amazon embayment ", by W. Rüegg (Peru) and D. Fyfe, read by J. V. Harrison. Ganzo Azul obtains light oil from the Cretaceous at depths of about 1,000 feet. Permian beds occur below the Cretaceous. Rüegg and Fyfe also noted the large stratigraphic gap underneath the Lower Cretaceous, and pointed out that both conformable and angular contacts were known. Differences in age, mobility, and position of the individual structural blocks of this region were postulated to explain this feature.

In their paper on " The Atlantic Coastal Plain ", read by R. R. Wheeler (U.S.A.), H. W. Straley (U.S.A.) and H. G. Richards (U.S.A.) reviewed the stratigraphy of the coastal plain between New Jersey and Florida. Numerous deep water- and oil-wells have provided new information on this area. The authors concluded that the oil possibilities of the coastal plain cannot yet be said to have been adequately tested, and they suggested that the Berlin–Salisbury embayment in Maryland, the Pamlico Sound basin in North Carolina, the Beaufort basin in South Carolina, and the Okefeeoke basin in south-eastern Georgia and north-eastern Florida merit further testing. In discussing Straley and Richard's paper, R. B. Campbell (U.S.A.) remarked that the Cape Hatteras well (North Carolina) had revealed a marine section regarded as favourable for oil occurrence. Palaeozoic formations, predominantly black shales, had been discovered beneath

the Mesozoic and Tertiary in the Florida–Georgia region, thus revealing the south-eastern margin of the ancient land mass of " Appalachia ", which hitherto had been regarded by many as lying far out in the Atlantic.

The concluding paper was by T. D. Weatherhead, on " Air survey and geology ". After enumerating the types of information and the advantages which can be obtained by the use of aerial photography, Weatherhead described the types of aircraft employed, the equipment used in the photographic flights, and the apparatus and techniques used in map production. Stereoscopy, the obtaining of geological information from the photographs and the most suitable photographic scales were briefly discussed.

Section F. Geology, Paragenesis, and Reserves of the Ores of Lead and Zinc

By K. C. Dunham

Introducing the work of the section, Professor W. R. Jones remarked that the eight years which had passed since the decision to include a symposium on lead and zinc ores in the programme of the Eighteenth International Geological Congress was taken had witnessed great changes in the industrial position of these minerals ; they were now among those most seriously in short supply. At present 70 per cent of world output came from only five countries, and half of this originated in the U.S.A. Moreover, during the present century as much lead and zinc had been mined as in the whole of previous history.

Members of the session had before them a specially prepared symposium containing twenty-three papers covering the principal genetic types of lead and zinc deposits, contributed by experts from all parts of the world, and edited by K. C. Dunham. In summary form the geological features of the 114 principal lead-zinc districts of the world were correlated with data on reserves and production. The data suggested a life of nineteen years for lead and twenty-six years for zinc at the current rate of production.

The increasing importance of the high-temperature deposits of Northern Sweden was evident from descriptions by Erland Grip (Sweden) and Nils H. Magnusson (Sweden). Another potentially important new source, discovered in 1936 at Mpanda, Tanganyika, but only now being brought into production, was the subject of a paper by the discoverer, J. de la Vallée Poussin, presented by R. B. McConnell (Tanganyika). In discussion of this paper, and of another by R. A. Mackay describing deposits in Nigeria, the important fact emerged

that in the tropics very few lead-zinc deposits have been found. Speakers, including W. D. Johnston, jun. (U.S.A.), drew attention to the possibility that this was because weathering was very deep and complete ; beneath the surface layer important deposits may remain undiscovered. At Mpanda there is still evidence of oxidation at a depth of 2,300 feet, but Poussin suggested that much of the weathering here was probably accomplished in Pre-Cambrian times. Further investigation of the effects of tropical weathering upon lead-zinc deposits is evidently desirable ; Mackay maintained, for example, that under certain conditions in the tropics, galena might be precipitated near the water-table, an effect unknown in temperate climates.

Second only to the United States among world producers of lead and zinc ores, Mexico contains many important mines, though as yet the geology of few of them has been recorded in the literature. J. Gonzalez Reyna (Mexico) presented a valuable review of the situation, and concluded that the northern part of the Republic, along the western Sierra Madre, offers most promise for new discoveries.

Emphasis was moved from new discovery to adequate development and equipment in existing fields by C. B. Forgan in describing the Stantrg Mine in Yugoslavia, developed by British interests before the war. Forgan considered that what is required in the immediate future is the creation of economic conditions capable of providing stimulus and long-term confidence in investigation and equipment of known potentialities.

Further important contributions to the geology of lead and zinc fields in the Mediterranean region were made by S. Vardabasso and P. Zuffardi (Sardinia), by J. Agard, J. Bouladon, F. Permingeat, and G. Jouravsky (Morocco), by P. Sainfeld (Tunisia) and G. Marinos (Greece). Published estimates of reserves for this region appear from this survey to be decidedly too low, a reassuring fact for the future of European non-ferrous metals industries.

Describing the widespread dissemination of small amounts of galena and blende in deposits of Permian age in Poland, Germany, and the north of England, T. Deans maintained that these represented the best examples of syngenetic deposits. The new data showed that more lead and zinc than copper is present in the Kupferschiefer, when this formation is viewed as a whole.

Epigenetic deposits in limestone, of moderate—to low—temperature type were described from Millclose, Derbyshire, by J. Shirley ; and by D. di Colbertaldo (Italy), from Raibl, Cave del Predil.

The whole discussion gave promise of activity in many parts of the world by geologists in an effort to contribute both to the immediate problem of ensuring adequate supplies of the metals and to the fundamental problems of the origin and emplacement of lead-zinc deposits.

Section G. The Geology of Sea and Ocean Floors

By W. B. Harland

The papers read to this section did not result in any general conclusions, but rather demonstrated a great development in the organization and technique of survey. In this respect the increasing co-operation of Navies with University departments is shown to result in a new order of available data. In addition, however, there is a considerable increase in the number and variety of purely academic attempts at ocean exploration.

At the first meeting, with Professor O. T. Jones, and subsequently Professor J. S. Lee (China), in the Chair, the following presented papers: J. Bourcart (France), R. D. Russell (U.S.A.), R. A. Sonder (Switzerland), A. C. Tester (U.S.A.), J. H. F. Umbgrove (Netherlands), and J. W. Wells (U.S.A.); and at the second meeting, with Professor J. H. F. Umbgrove (Netherlands) and Dr. R. M. Field (U.S.A.) in the Chair, E. M. Gallitelli (Italy), R. M. Field, J. S. Lee, Z. Sujkowski (Poland), and P. H. Kuenen (Netherlands) read papers, and the last showed a film.

The data presented indicated but briefly what was in many cases already published or to be published elsewhere. Developments in exploration technique include improved echo sounding which has been extensively used in detailed surveys of many continental shelves and pacific islands. Submarine photography is a new and promising contribution to geology. New designs for submarine exploratory vessels are expected. Seismic and gravity surveys are also being extended increasingly to the seas and oceans. An ambitious programme of surface drilling in Bikini was described. Sampling by submarine coring devices is being rapidly developed and, in addition to increased knowledge of contemporary marine deposits, there is the prospect in the next few years that ocean stratigraphy may challenge many current ideas on the later history of the earth.

All these methods have been known and used before. The present stage marks an intensification of effort when the isolated data so far described may be found to be more or less typical of widespread conditions. The results of different techniques are being co-ordinated as never before as, for instance, in the U.S. Navy exploration of Bikini Atoll.

Certain generalizations were attempted and the pattern of ocean geology in the next decade may be discerned. The nature of sedimentation at great depths as reflecting differing conditions remains an important field of research. For instance, the chemical changes involved in the formation of manganese nodules was discussed. It seems that submarine canyons are characteristic of continental shelves

rather than an interesting exception, and their formation remains a mystery though it is probable that high density turbidity currents as well as slumping operate in them. It may be possible, especially when the submarine surface has been further explored, to demonstrate certain preferred levels as indicated by submarine features such as continental shelves, island terraces, canyons, and mountains, and so disentangle widespread isostatic from superimposed eustatic changes. Such an attempt was made at this meeting. The Pacific ocean, with its coral islands, is the area where this problem is most actively pursued, and further light on the structure and movements of the floor of the Pacific may be expected. Island arcs, as in S.E. Asia, begin to show a characteristic structural pattern, and speculation on their origin supported by geophysical data may lead to a working hypothesis of orogenesis. The venerable concept of the geosyncline comes again under review and in modern dress seems likely to retain a leading role. The next decade may well define that dress.

Section H. The Pliocene-Pleistocene Boundary

By K. P. OAKLEY

Professor W. B. R. King, who acted as Chairman of this symposium, outlined the various criteria which have been proposed for delimiting the Pleistocene, and stressed the desirability of selecting a type locality where one or more of these theoretical concepts can be tied to actual strata. He favoured Italy as type area, and suggested that the question to decide was whether the lower boundary of the Pleistocene should be drawn at the base of the Calabrian-Villafranchian, or at the top.

H. L. Movius (U.S.A.) reviewed the stratigraphy of the Villafranchian deposits of Italy, East and Central France, and drew the conclusion that they were approximately contemporary with the onset of glaciation in the Alps.

In a joint discussion with Section K (The Correlation of Continental Vertebrate-bearing Rocks) A. T. Hopwood called attention to the practical value of regarding the Villafranchian as basal member of the Pleistocene, since it was distinguished by a widespread mammalian fauna, including *Elephas*, *Equus*, and advanced bovines, which permitted correlation from continent to continent. Mlle. M. Friant (France) spoke of the importance of elephants as guide-fossils in the Pleistocene.

F. E. Zeuner pointed out the difficulties inherent in the use of glaciation or the appearance of certain mammalian genera for delimiting the Pleistocene, since these criteria were inapplicable in non-glaciated or unfossiliferous regions. He favoured physiographic criteria, and

suggested that the drop in sea-level from around the 100-metre mark during the Sicilian stage would afford one possible boundary for the base of the Pleistocene, since it initiated a new erosional cycle widely recognizable on the continents. He was of opinion that the cool elements in the Villafranchian fauna and flora might correspond with the Pre-Günz (Donau) phases of glaciation in the Alps, but further work was needed to prove this correlation. Villafranchian deposits were of great thickness, and if the Pleistocene were extended to include them the Lower Pleistocene would be out of proportion to the Middle and Upper.

P. Woldstedt (Germany) reviewed the evidence of early glaciations in Europe. In periglacial parts of Germany there were six so-called "preglacial" terraces, some of which probably recorded Eberl's Donau (Pre-Günz) phases of glaciation.

The various criteria which have been used in the East Indies for delimiting the Pleistocene were discussed by G. L. S. Sibinga (Netherlands). He found marine regression, based on glacial eustasy, the most convenient. R. J. Russell (U.S.A.) also found physiographic criteria the most practical. He recounted evidence from bores 30 miles from the shore in the Gulf of Mexico, which proved an oxidized zone in sediments below Recent marsh-delta deposits at a depth of 550 feet, clearly marking the late Pleistocene regression of the sea.

E. Feruglio (Argentine) contributed an account of the marine terraces in Patagonia. The molluscan faunas of the higher terraces (170–186 m., 115–140 m.) contained 30–40 per cent extinct species, and he regarded them as Upper Pliocene. The main Pleistocene terraces are at elevations of 45–95 m., 15–30 m., and 8–12 m.

C. I. Migliorini (Italy) reviewed recently obtained data regarding the marine succession in Italy, and claimed that the base of the Pleistocene was best drawn between the Astian and the Calabrian, since faunal change at this horizon is well marked, whereas the Calabrian and Sicilian are scarcely separable palaeontologically. Moreover, there is evidence of pronounced climatic cooling between the Astian and the Calabrian.

R. Selli (Italy) gave an account of his work with G. Ruggieri (Italy) on the Plio-Pleistocene stratigraphy in Emilia (North Italy), and made out a strong case for regarding the Calabrian (*sensu stricto*), which he regarded as equivalent to Pre-Günz and Günz, as the basal stage of the Pleistocene. A new unit, Calabrian II or Emilian, with mild climate fauna, is recognizable between Calabrian (*s.s.*) and Sicilian. The speaker indicated that two sets of deposits had been classed as "Sicilian", the earlier being Sicilian *sensu stricto*, the later equivalent to Milazzian.

In a written communication, J. M. Ribera-Faig (Spain) reported

that continental beds of Astian age in the Catalonian province of Spain, were followed by erosional stages, caliche formation, and river terraces, the higher of which contained Lower Pleistocene fauna.

A. Desio (Italy) outlined present-day knowledge of the Pliocene and Pleistocene geology of Libya. The presence of marine deposits of Pliocene age in Libya is still uncertain. The Mio-Pliocene continental beds with mammalian remains at Sahabi, Sirtica, are most important for correlation with other countries.

C. Arambourg (France), in a written communication, and L. S. B. Leakey (Kenya) discussed the Pleistocene stratigraphy and palaeontology of Africa, especially the application of the terminology advocated at the Pan-African Congress on Prehistory (Nairobi, 1947). Leakey pointed out that in East Africa, deposits of the Kageran stage (whose fauna is equivalent to the Villafranchian) contained pebble-tool industries, representing the earliest known human cultures. It was logical and convenient, he said, to regard this stage as forming the base of the Pleistocene. For faunal and geological reasons it appeared desirable to divide the Kamasian into lower and upper stages. According to Arambourg, the classification of the Pleistocene recommended at Nairobi (*L'Anthropologie*, 51, p. 258) is proving applicable to the North African as well as to the East African faunal succession. He said that the Neanderthaloid jaw, found at Rabat, Morocco, was associated with an Upper Kamasian fauna.

C. C. Young (China) submitted a paper in which he discussed the question as to whether the lower boundary of the Pleistocene in China should be placed at the bottom or at the top of the Nihowan stage. The latter boundary (i.e. approximately base of Choukoutien stage) has been adopted by the Caenozoic Research Laboratory.

According to D. N. Wadia (India) no definite natural break serving to separate Pleistocene from Pliocene can be discerned in the great thickness of deposits preserved in the N.W. Sub-Himalayas.

G. H. R. von Koenigswald (Netherlands) outlined recent discoveries of fossil man in Java. He said that remains of three types of man had been recovered from deposits now classified by most workers as Lower Pleistocene : *Pithecanthropus robustus* Weidenreich (probably synonym of *P. modjokertensis* (v. Koenigswald)) ; *P. dubius* v. Koengiswald, and *Meganthropus palaeojavanicus* v. Koenigswald. The speaker claimed that the Trinil Beds, which yielded the genotype of *Pithecanthropus*, were later, and should be classed as Middle Pleistocene. He equated the Trinil Beds with the Choukoutien stage of China.

H. E. Thalmann (Venezuela), in a paper submitted in writing, discussed the foraminiferal evidence of a Pliocene-Pleistocene boundary. He noted five genera of foraminifera restricted to the Pleistocene : *Bifarinella*, *Geminospira*, *Oolitella*, *Polymorphinoides*, and *Unicosiphonia*.

I. M. van der Vlerk (Netherlands) and A. J. Pannekoek (Netherlands) spoke on behalf of a team of workers now actively engaged on elucidating Plio-Pleistocene stratigraphy and palaeontology in the Netherlands. On the basis mainly of foraminiferal evidence, van der Vlerk claimed that in the East Anglian succession the base of the Butleyan was the natural place to draw the Plio-Pleistocene boundary. A marked recession of the sea occurred during this stage. Moreover, elephants made their first appearance in the equivalent continental beds in the Netherlands (*Archidiskodon planifrons* in the Prétiglian stage). F. Florschütz (Netherlands) and Miss A. M. H. van Someren (Netherlands) submitted a paper on the palaeobotanical boundary Pliocene-Pleistocene, and showed that the Reuverian (Upper Pliocene) and Tiglian (Lower Pleistocene) clays can be separated by pollen-analysis.

While the discussions of Section H were taking place, the Council of the Eighteenth Session appointed a Temporary Commission to advise on the definition of the Pliocene-Pleistocene boundary. The Commission was able to forward a unanimous opinion in the following terms :—

(1) The Commission considers that it is necessary to select a type-area where the Pliocene-Pleistocene (Tertiary-Quaternary) boundary can be drawn in accordance with stratigraphical principles.

(2) The Commission considers that the Pliocene-Pleistocene boundary should be based on changes in marine faunas, since this is the classic method of grouping fossiliferous strata. The classic area of marine sedimentation in Italy is regarded as the area where this principle can be implemented best. It is here too that terrestrial [continental] equivalents of the marine faunas under consideration can be determined.

(3) The Commission recommends that, in order to eliminate existing ambiguities, the Lower Pleistocene should include as its basal member in the type-area the Calabrian formation (marine) together with its terrestrial [continental] equivalent the Villafranchian.

(4) The Commission notes that according to evidence given this usage would place the boundary at the horizon of the first indication of climatic deterioration in the Italian Neogene succession.

The Commission's recommendations were unanimously accepted by the Council at its meeting on 1st September, 1948. Some of the implications of the definition recommended are discussed in *Nature*, 163, p. 186.

Section J. Faunal and Floral Facies and Zonal Correlation

By H. Dighton Thomas

Dr. A. E. Trueman, followed by Professor B. Sahni (India), in the First Session; Professor R. Kozlowski (Poland) and Professor G. G. Delépine (France) in the Second Session; and Professor C. Poulsen (Denmark) and Dr. A. E. Trueman in the Third Session, acted as successive Chairmen.

A. Renier (Belgium) clearly posed the problem of faunas and floras in making correlations and their importance to stratigraphy, palaeogeography, and palaeoclimatology, and argued that age and facies should be considered together. Local correlations are not capable of unlimited extension, and palaeontological knowledge should be applied with intelligence. L. R. Wilson (U.S.A.) showed how fossil spores and pollen from some early Tertiary coals and shales of Montana and Wyoming not only give information on the correlation of the rocks, but also throw light on the palaeoecology and palaeoclimatology of those areas at that time. S. J. Dijkstra (Netherlands) demonstrated the value of megaspores in the correlation of Turkish coal deposits. From an analysis of the flora of the Lower Brown Limestone of North Wales, W. S. Lacey suggested that that limestone should be correlated with the lowest part of the Scottish Oil Shales and the equivalent beds in Northern England, and claimed that there is faunal support for this. T. N. George pointed out the dangers of this correlation made by jumping from the Avon Gorge to North Wales and thence to Scotland, since big facies changes are involved. He elaborated this theme in the Second Session in a paper on Tournaisian facies in Britain, in which he pointed out that the restricted Tournaisian fauna in northern Britain makes correlation very difficult, and suggested that some rocks of Old Red Sandstone facies may be of Carboniferous age in the Midland Valley of Scotland. T. S. Westoll emphasized the importance of the *Bothriolepis–Holoptychius–Phyllolepis* fauna in discussions on the boundary between the Upper Old Red Sandstone and the Lower Carboniferous.

Y. C. Sun (China) discussed the Palaeozoic faunas of Asia and Europe, and concluded that the Pacific was a main centre of dispersal of early Palaeozoic life. He claimed that the completeness of the Yunnan succession made it the best standard in classifying the world's Palaeozoic, and he showed there was a close connection between the Mediterranean Sea and the Cathaysian Province. His ideas were welcomed by G. G. Delépine (France), who quoted Devonian and Carboniferous goniatites, as well as fusulinids, in support. A. Lamont analysed the Silurian fauna of the Pentlands, particularly the Gala-Tarannon, and claimed a new division, the Pentlandian, of the Silurian

system. In the discussion on a paper by E. B. Branson (U.S.A.) and M. G. Mehl (U.S.A.), who showed how conodonts have been used in correlating stages, B. F. Howell (U.S.A.) drew attention to two impressions of what appear to have been fish plates in the Middle Cambrian of Vermont. L. S. Librovich (U.S.S.R.) discussed the faunistic subdivision and correlation of the Lower Carboniferous of the U.S.S.R., and emphasized that on faunal grounds the Namurian in Russia is better classified with the Lower Carboniferous than with the Middle Carboniferous, though, as Trueman later pointed out, the greater part of the Namurian in Britain and Western Europe forms a natural part of the Upper (or Middle) Carboniferous. J. J. Gorsky (U.S.S.R.), discussing the coral zones of the Upper Palaeozoic of the Urals, showed that the coral fauna of Pz3 is a local one, which has developed from an Upper Viséan fauna, and that it is of restricted value in correlation: he emphasized the importance of narrowly defining species.

In the closing Session T. M. Harris showed that in the flora of the Yorkshire Estuarine Series many plant species are frequent in the first and last of its four stages, but absent from its two middle ones, while others characterize the two middle ones alone. He objected to the term "Estuarine" and preferred "Deltaic" as more appropriate, but P. C. Sylvester-Bradley favoured the former on the grounds of priority. There were two papers on fresh-water mollusca of the Mesozoic by T. C. Yen (U.S.A.), who claimed that parallel development took place in them contemporaneously in separated basins, and that the stages reached in the evolution of shell characters could be used for correlation. On this basis he inferred that the Morrison formation of North America is probably older than the greater part of the Purbeckian of N.W. Europe, and that it possibly represents a freshwater facies of the Portlandian. Two papers by K. F. G. Mullerried (Mexico) dealt with the marine and continental facies of the Mesozoic of Mexico and Central America, particularly the Cretaceous. A final paper, by A. N. Thomas (Iran), demonstrated variation in the foraminiferal biofacies of the Asmari Limestone of Iran.

In a valuable summing-up of the discussions of the Section Trueman pointed out how various are the organisms now used for correlation by palaeontologists; even some of the most unpromising are important locally. Some local correlations have proved applicable over unexpectedly wide areas, but others naturally broke down when similarly extended, especially if they were dependent on facies. Both faunal and floral evidence are valuable and, if proper regard be had for facies variations, must lead to the same conclusion. But where the evidence is incomplete correlations must be recognized as only tentative. Trueman emphasized the difficulties in erecting a satisfactory and

universally acceptable stratigraphical classification, and mentioned the placing of the Namurian as a good example. The narrower stratigraphical divisions can generally be identified only over lesser horizontal distances ; world-wide correlations must be based on broad divisions whose boundaries become increasingly vague with distance.

Section K. The Correlation of Continental Vertebrate-bearing Rocks

By W. E. Swinton

Professor D. M. S. Watson acted as Chairman throughout and introduced the subject matter of each session. At the first session T. S. Westoll dealt with the vertebrate-bearing strata of Scotland in the light of his own researches. His conclusions are that the so-called Downtonian fish bed of Lesmahagow and the Pentlands is earlier than Downtonian but later than Llandovery-Valentian. The Cowie Harbour fish bed is Downtonian and Upper Downtonian faunas are not known. The main fossiliferous horizons of the " Lower Old Red " are Dittonian. He regards the Old Red Carboniferous boundary as arbitrary and thinks the Lower Calciferous Series may be the equivalent of the *Remigolepis*-zone and higher beds of Greenland. E. Stensiö (Sweden) objected to this last assumption on the ground that the vertebrate faunas were not directly comparable.

T. S. Westoll believes that the Lepospondyli, the oldest vertebrates in Scotland, are of Middle and late Visean age, and that the vertebrate faunas of the Productive Coal Measures are Westphalian A-B.

E. J. White discussed the palaeontological zoning of the Downtonian and Dittonian strata of the Welsh borders, and gave the division between the two as the base of the zone of *Pteraspis leathensis.* He believes that the natural palaeontological break in this region between the Silurian and the Old Red Sandstone is at the base of the Ludlow Bone Bed, and he therefore concludes that the Downtonian strata should be included in the Devonian as part of the Old Red Sandstone.

The second session of Section K was a joint one with Section H and is already summarized under the proceedings of that Section. The proceedings were remarkable for the unanimity of the specialists in accepting the inclusion of the Villafranchian in the Lower Pleistocene.

The final meeting covered a wide stratigraphical range, from the Lower Trias to the Miocene. Mlle. M. Richard (Algeria) stressed the stratigraphical importance of the mammalian faunas of the Eocene, Oligocene, and Miocene, illustrating her remarks by reference to the French succession. D. M. S. Watson stressed the importance of this succession and said it was time that a serious attempt was made to

correlate it with the American sequence. T. M. Stout (U.S.A.) said that the work done on the Great Plains mammal succession, from the base of the Oligocene to the Pleistocene, made such a correlation much less difficult.

S. P. Welles (U.S.A.) gave an account of the very comprehensive collection of Amphibia he had made in the Trias (Moenkopi) beds of Northern Arizona, where in one locality he found numerous examples of forms, like *Aphaneramma*, *Capitosaurus*, and *Cyclotosaurus*, otherwise represented by unique, or very few, specimens from Spitsbergen, Germany, and South Africa.

E. H. Colbert (U.S.A.) described a remarkable find of dinosaur remains in the Upper Triassic (Chinle) beds of New Mexico. The principal discovery was a series of skeletons of *Coelophysis*, a small Theropod known as far only from fragments. The new material will not only give full details of the skeleton, but should provide evidence as to age, and perhaps sexual, differences in these interesting reptiles.

Section L. Earth Movement and Organic Evolution

By H. L. Hawkins

In his introductory remarks the Chairman, Professor H. L. Hawkins, stressed the importance of the topic with which this section was concerned. The problems of the relation between environmental changes and the evolution of organisms are fundamental to both geology and biology, for faunal and floral facies and migrations may seriously affect the correlation of disconnected strata, while the adaptation of organisms to their surroundings is a major aspect of the study of evolution.

The six papers presented to the section covered a variety of topics, some local, others regional, and others world-wide. They are here taken in an order consistent with that grouping, and not in the order of their reading.

L. V. Cepek (Czechoslovakia), in his paper entitled " Palaeozoic earth-movements and organic evolution ", gave a detailed account of the stratigraphy of the Coal Measures in some Czechoslovakian coal-basins, and showed the relation between contemporary rift-faulting and the quality and quantity of coal developed in different parts of the basins ; the thickness and rank of the coals reflecting the varying circumstances of their accumulation.

D. Andrusov (Czechoslovakia), speaking on " Mouvements orogéniques, sédimentation et évolution de la vie dans les Carpathes occidentales ", gave a summary of the stratigraphical and tectonic history of the district, and discussed the influence of these phenomena

on the faunal successions. He laid special stress on the connection between bathymetric conditions and the nature of the fauna, and on the influence on migration of the opening and closing of routes of communication by tectonic movement.

A. Chavan (France) read a paper " Sur les causes de certaines migrations de faunes avant et pendant l'Eocène ", in which he covered a wider geographical field but a more restricted stratigraphical range. After describing the occurrence of many genera of tropical Mollusca in the Lower Cainozoic systems of north-west Europe, he suggested that it might be explained as the result of migration made possible by great geographical changes, including the development of the Atlantic Ocean.

A paper by V. A. Obruchev (U.S.S.R.) on " The fundamental features of the Kinetics and plastics of neotectonics " was, in the absence of the author, read in title only. In it the influence of orogenic and climatic changes on organic evolution was carried up into the Pleistocene.

K. Zapletal (Czechoslovakia), in his paper on " Geochemie, Rhythmus der Sedimentation und organische Entwicklung im Lichte der Tektogenesis ", ranged over still wider territory, correlating orogenies and sedimentary cycles the world over, and throughout geological time, with magmatic modification and the succession of organic life. He indicated the close relation between times and places of vigorous tectonic activity and centres of important organic evolution and dispersal.

Lastly, R. C. Moore (U.S.A.) discussed the matter from a biological rather than a tectonic angle, demonstrating in the group of the Crinoidea the coincidence between the inception and extinction of the several divisions of the group and the main orogenic paroxysms of geological history. His detailed analysis of the distribution in time and space of the various orders of Crinoidea gives valuable evidence of palaeogeographical changes, and of the faunal response to them as shown by migration, extinction, and evolution.

Section M: Other Subjects

By R. M. Shackleton

The Other Subjects Section (M) of the Congress, under the Chairmanship of Sir Edward Bailey, with Professor Leon Collet (Switzerland) as alternative Chairman, held six sessions, at which twenty-seven papers were presented.

The majority of the papers dealt with tectonic problems—with earth movements and structural geology; it was therefore fitting that

L. Collet (Switzerland) should begin by presenting to the Congress the first four of eight geological sheets which will cover the whole of Switzerland, where better than anywhere else in the world, the amazing results of the movements of crustal strata are laid bare to the geologist. The maps co-ordinate an immense body of work and will be of value to tectonicians the world over.

Relative Movements of the Land and Ocean Surfaces

Several papers were concerned with this subject. An unusually fine series of stranded Pleistocene sea-beaches in South Australia was described by R. C. Sprigg (Australia). Climatic conditions favoured rapid surface calcification of the dunes, which were thus preserved intact. Some seventeen sea-level maxima, superimposed on a generally falling sea level, suggested at least a numerical similarity with the number of maxima predicted in the Pleistocene period by the theories of Milankovitch and Zeuner. In discussion, F. E. Zeuner, impressed but cautious, summed up his remarks by saying " we have in our curve a possible seventeen maxima. R. C. Sprigg has about the same number. Let us take note of this agreement."

A fundamental paper by L. von Post (Sweden), presented by N. G. Hörner (Sweden) showed, by analysis of the wealth of data from Sweden, that various factors governing the late Quaternary displacement of the sea shore could be separated and evaluated. Besides eustatic changes of sea level and isostatic rise of the land after the removal of the load of ice, it was also necessary to postulate pulsatory movements of subcrustal material. A. J. Bull discussed the correlation of river terraces and sea levels in southern England through the Pleistocene period.

Earthquakes and Tectonics of Turkey

The relation between earthquakes and major tectonic features of Turkey was the subject of a paper by H. N. Pamir (Turkey). M. M. Blumenthal (Turkey) discussed the tectonics of Turkey, referring especially to the variable direction of crustal movement in different parts of the region during the Alpine orogeny.

Gravitional Sliding in Orogeny

The part played by sliding under the influence of gravity was the subject of a series of papers. L. Collet (Switzerland) discussed the various possible interpretations which might be applied to explain masses of granitic or other crystalline rocks embedded in a sedimentary series. Describing the evidence in certain particular cases in the High Calcareous Alps, he inferred that these were probably best interpreted as submarine landslip masses, which slid into the Jurassic sea. This

would imply a mountainous Jurassic topography. It is now known, said L. Collet, that such a Jurassic landscape did exist there.

W. J. McCallien (Turkey) and M. Tokay (Turkey) produced striking evidence for a slumped or landslide origin of great masses of Carboniferous rocks (one so large that coal is mined in it) which are embedded in the Cretaceous rocks of the Black Sea region between Zonguldak and Eregli.

A more revolutionary conception of the part played by sliding in orogeny was advanced by C. I. Migliorini (Italy) and supported by G. Merla (Italy) to explain the nature and relationships of the *Argille scagliose*, which forms the so-called Ligurid nappe of the Apennines. According to Migliorini, this nappe, which in places rests on formations as young as Pliocene, is supposed to have advanced some 200 km., yet it is nowhere more than a few hundred metres thick and it was never over-ridden. It could not have been pushed from behind. The evidence indicates movement under gravity. The mechanism suggested is the upthrust of a series of crustal wedges, bounded by downwardly convergent normal and reversed faults; orogenic landslips developed from each successively uplifted wedge, leaving behind tectonic wrecks scarred by tectonic erosion.

In the discussion, G. M. Lees objected to the use made of the conception of isostasy to explain the recurrent uplift of the wedges after their tectonic denudation. The Alpine geologists were not drawn into the discussion, of which more will no doubt be heard.

Carrying the idea of sliding further into the depths of the crust, J. L. Rich (U.S.A.) outlined a theory of orogenesis based on the idea that the crust slides off the edge of sheets of magma which develop owing to radioactive heating. R. M. Shackleton thought that on this theory one would expect orogenic girdles marking the limits of the magma sheets, whereas the dominant orogenic pattern seemed to be linear; Rich pointed to the West Indian loop and other such patterns as favouring his idea. J. P. Marble (U.S.A.) mentioned recent Swedish work which shows that the radioactive isotope of potassium (K 40) has a greater radioactivity than was formerly thought and probably contributes more heat to the earth's crust than Uranium and Thorium together. Therefore the depth at which radioactive melting would happen would be less than was thought. This agrees with Rich's interpretation.

Tectonics of the Older Mountain Systems of Northern Europe, Greenland, and North America

Great advances have been made in the knowledge of the old mountain systems of the northern regions. In Greenland the young Geological Survey has established the existence of a previously unknown

ancient orogeny. The evidence was described by A. Noe-Nygaard (Denmark). O. Holtedahl (Norway) discussed the relation between the Norwegian Caledonides and the Alps in the light of new work. He showed how much that had at one time been referred to the pre-Caledonian basement was in fact reconstituted during the Caledonian orogeny.

In the Scottish Highlands, papers by E. B. Bailey and W. Q. Kennedy and E. B. Bailey and C. E. Tilley provided a wealth of evidence—stratigraphical, petrological, and structural—to show that the Torridonian, with its basal conglomerate resting on Lewisian gneiss, can be traced from the foreland, through successive nappes in which the metamorphism increases gradually, into the Moine nappe above the Moine thrust. The Moine schists are thus demonstrated to be the metamorphic equivalents of the Torridonian Sandstones. Their tectonics and metamorphism are Caledonian. This great step forward in Highland geology met little critical opposition, though A. G. MacGregor found that the petrological criteria upon which Kennedy's distinction of Moines from sub-Moines was partly founded were not valid. Kennedy recapitulated the field evidence that the sub-Moines are a tectonic unit distinct from and below the Moines, but admitted the possibility of tectonic intercalations of Moines within the lower tectonic unit.

Still further south, in France, A. Demay (France) showed how it had been possible to trace a detailed tectonic, stratigraphic, and magmatic continuity from southern Armorica into the French Central Massif.

Across the Atlantic the evolution of the mountain systems bordering North America was described by Marshall Kay (U.S.A.). He showed that the conception of vanished borderlands from which the geosynclines were fed with sediment cannot be sustained. Instead, there is evidence of island arcs, largely volcanic, comparable to the east Asian arcs of the present day.

The Andes

An account so brilliantly delivered by E. Feruglio (Argentine) that even those little familiar with his language could follow it, showed how great has been the progress in the mapping and exploration of that region. A. Heim (Switzerland), introduced by E. B. Bailey as the " young Heim; young, that is, to those who are older ", described the results of his explorations in the central and northern Andes, demonstrating the folds and unconformities in aerial photographs. Alpine style tectonics, however, he found nowhere in evidence.

Magma and Earth Movements

M. Vuagnat (Switzerland) gave the results of a comparative petrological study of the pillow-lavas of the Pre-Alps and those of Britain.

He concluded that the only British pillow-lavas strictly comparable to those of the Alps are those in the Mona Complex of Anglesey. In the discussion A. K. Wells emphasized again the independence of the terms pillow-lava and spilite. O. T. Jones described evidence which shows that certain pillow-lavas were intrusive, presumably into soft muds.

Beautiful examples of cauldron subsidences were mapped many years ago by Brögger in the Oslo region of Norway, but never described. The description now given by C. Oftedahl (Norway) exposed many features of interest.

Earth Movements and Mineralization

Two papers dealt with this theme. Both showed how closely provinces of mineralization correspond with the major tectonic divisions. J. Westerveld (Netherlands) dealt with the East Indies, outlining the geological and metallogenetic history of the region with the aid of a very fine map. A. W. Jolliffe (Canada), describing the results of co-ordinated geological and prospecting work from the air and on the ground, showed that in the north-western part of the Canadian Shield four tectonically distinct zones were each characterized by a distinct mineralization ; some spectacular aerial photographs were shown of straight transcurrent faults, some of which are traceable for several hundred miles across the Shield.

Other Topics : Semi-Permeable Barriers in Mineralization ; Splits and Washouts in Coal Seams ; Frozen Soil Phenomena

R. A. Mackay provoked a lively and mainly favourable discussion in outlining his theory of semi-permeable barriers as a major factor controlling ore deposition. A. A. Thiadens (Netherlands) and J. I. S. Zonneveld (Netherlands) described the relationships seen in washouts in peat deposits and discussed criteria by which the economically important distinction could be made between splits and washouts in coal seams. Q. Zaruba (Czechoslovakia) described frozen-ground structures of Pleistocene age in Czechoslovakia, which were found to be important in engineering problems. The ensuing discussion showed that comparable structures are widespread in northern Europe.

Association of African Geological Surveys

By F. Blondel

The Association of African Geological Surveys, a Sub-Commission of the International Geological Congress, held a series of open meetings

in London during the Congress. The Bureau of the Association, elected during the session, consists of Sir Edward Bailey, Honorary President, Dr. F. Dixey, President, and Mr. F. Blondel, Secretary.

At the first meeting of the Association the Secretary reported on the progress of the preparation of the 1 : 5,000,000 International Geological Map of Africa. This map, which is being produced by the close co-operation of all the African geological surveys, will consist of nine sheets. The first sheet was published in 1936 ; and in spite of delays caused by the war the work is nevertheless making good progress. Four completed sheets were presented to the Congress, and two others are ready for printing. There was every hope that the map will be complete before the next session of the Congress. It will be of very great value in the study of all African geological problems.

In view of the success of this enterprise, the Association requested the Secretary to prepare a general tectonic map of Africa and a general map of the mineral occurrences of the continent. Such maps will also be of great value, both to geologists and mining engineers.

The Association had asked its constituent Surveys to prepare in advance of the Congress brief regional accounts of recent developments in African geology. Fourteen reports were presented, covering almost the whole of the continent of Africa, and will be published in the Report of the Congress. They will form an excellent review of recent geological work in Africa.

The preparation of the map had indicated the need for discussion of certain general problems of African geology, and this was arranged during the meetings of the Association. Among these was correlation in the Precambrian rocks in which metamorphism and the absence of fossils make the application of ordinary geological methods very difficult. A brilliant exposition by A. Holmes of the utility of radioactive methods in the determination of the age of granites enlarged the scope of the discussion and opened up vistas of remarkable discoveries in the future. The study of certain debatable structures known as stromatolites was also a subject of discussion, and the assistance of palaeontological specialists was called in. Finally, still in connection with these ancient series, the evidence of glaciation afforded by their tillites was considered.

At the other end of the time scale the Association studied certain recent formations whose correlation has still to be determined ; attention was given to the division of the Pleistocene as a whole, as set out by the first Pan-African Congress of Prehistory, which was held at Nairobi in 1947 ; and especially to the group of the Kalahari Sands.

Another very attractive topic, the formation and structure of the great Rift Valleys which cut East Africa for thousands of miles, and

which recur in the Jordan Valley, Palestine, was also the subject of many interesting papers.

In addition to these major topics, certain specialized problems were on the agenda, but lack of time permitted discussion of only one of these, the formation of carbonatites.

About thirty detailed papers describing the local geology of various districts scattered throughout the Continent were the final item in this review of the recent work in Africa.

This session of the Association was particularly active and successful. More than fifty geologists contributed to the discussions, and the close personal contacts created or renewed will greatly aid future research on the geology of the African continent.

The International Paleontological Union

By C. J. Stubblefield

The International Paleontological Union held three open meetings during the Eighteenth International Geological Congress in London in August and the subjects discussed at two of these were designed to have general appeal to palaeontologists. The first meeting took place with the President, Professor P. E. Pruvost (France), in the Chair. The papers communicated related to special aspects of palaeontological publication and bibliography and the first by H. L. Hawkins was a statement of the position in Britain. Reference was made not only to stratigraphical, morphological, and philosophical palaeontological writings but also to the Zoological Record and to S. A. Neave's *Nomenclator Zoologicus*, which indexed all generic names in Zoology and Palaeozoology introduced between 1758 and the end of 1935. Two further papers dealt with special publications appearing in the U.S.A. ; the first, by A. S. Warthin, jun. (U.S.A.), communicated by the Secretary, B. F. Howell (U.S.A.), announced progress of the Catalogue of North American Devonian Fossils ; and the other by Brooks F. Ellis (U.S.A.) described the history and continuation work of his and Miss A. Messina's Catalogue of Foraminifera. This was published in 1940 with assistance from the federal Works Projects Administration under the co-sponsorship of Mayor F. H. LaGuardia and the American Museum of Natural History. Three hundred and thirty copies of this Catalogue were printed, each bound in thirty loose-leaf ledgers containing about 1,200 pages apiece ; over 200 subscribers now possess the work and receive the issues of supplementary sheets. The present staff, maintained by generous grants from oil companies, comprises ten permanent and two temporary members. M. Lys (France) then outlined his project to reproduce unpublished plates of foraminifera

prepared and annotated early last century by Alcide d'Orbigny. To enable the collection of all primary illustrations and descriptions of fossils into card-index form, S. H. Haughton (South Africa) advocated that the formation of a salaried bureau of the Union should be considered. J. Roger (France) spoke of the abstracting and card-index work now undertaken at the Centre d'Etudes et de Documentation paléontologiques and proposed that the Bureau of the Union should be at Paris. Discussion of these papers was followed by a Council decision to defer plans concerning the proposed bureau until the results became known of the International Geological Congress Council's deliberations on the possible formation of an International Geological Union with an approach to UNESCO. An observer was appointed to report on these negotiations.

The Union's second meeting, with Vice-President A. Morley Davies in the Chair, was devoted to discussing the uses of Foraminifera in Stratigraphy. A series of papers by T. Barnard, Miss I. Crespin (Australia), J. Cuvillier (France), L. M. Davies, H. J. Finlay (New Zealand), R. Grill (Austria), Mme Y. Gubler (France), H. Hiltermann (Germany), P. Marie (France), C. D. Ovey based on work by H. J. Finlay (New Zealand), and I. M. van der Vlerk (Netherlands), dealt with the application of foraminiferal studies to the stratigraphy of the Mesozoic and Cainozoic formations of Europe, Australia, the East Indies, India, and New Zealand.

The third meeting was concerned with the Nomenclature of Fossils, and Vice-President W. J. Jongmans (Netherlands) occupied the Chair. F. Hemming gave an historical account of the work of the International Commission on Zoological Nomenclature and outlined some of the changes in the code formulated at the 1948 International Zoological Congress held in Paris. He announced that a revised edition of the code, incorporating agreed interpretations, would shortly be issued, and replied to questions raised in a long and interesting discussion. A paper by L. Strauz (Hungary) followed, urging the need for quadrinominal nomenclature, particularly for Cainozoic mollusca, in view of the multiplicity of generic and specific names.

Three meetings of the Union's Council were held, and at the concluding meeting the following officers were elected :—

President . .	A. Morley Davies.
Vice-Presidents .	H. J. Harrington, B. F. Howell, W. J. Jongmans, A. Kryshtofovich, J. Piveteau, B. Sahni, C. J. Stubblefield, Y. C. Sun, V. Van Straelen.
Secretary . .	H. E. Vokes, Johns Hopkins University, Baltimore, Maryland, U.S.A.
Treasurer . .	Leif Størmer, University of Oslo, Norway.

Meetings on the Mineralogy and Geology of Clays

By D. M. C. MacEwan

A series of three meetings, under the general heading " Mineralogy and Geology of Clays ", was organized by the Clay Minerals Group of the Mineralogical Society, in collaboration with the International Geological Congress. The papers were grouped under four headings :—

1. The hydrous micas.
2. The kaolinitic minerals.
3. Physicochemical reactions of clay minerals.
4. Origin of clay minerals.

The first subject was introduced with a joint paper by R. E. Grim (U.S.A.) and W. F. Bradley (U.S.A.), presented by R. E. Grim. Optical, chemical, X-ray, and differential thermal data for a series of illites and related specimens were given, together with a discussion of the question of distinguishing between the two-layer (muscovite-like) and the one-layer (biotite-like) type of structure. The fact was stressed that the illites, as micas, for which the crystallization is " three dimensionally static " are to be distinguished from mixed-layer crystallizations of mica and montmorillonite (e.g. bravaisite and sarospatite). Two new occurrences of illitic material were reported in subsequent papers—at Ballater, Scotland (by R. C. Mackenzie, G. F. Walker, and R. L. Hart), and in Toscana, Italy (by C. Andreatta). Both these occurrences were considered to be of hydrothermal origin. These papers were followed by a discussion on the use of the terms " illite ", " hydromuscovite ", etc.

Under the second heading were grouped a series of papers from the Leeds workers who have been investigating the kaolinite minerals. A. L. Roberts and R. W. Grimshaw described the isolation, in relatively pure form, of the " fireclay type " of kaolinite mineral, which has previously been described by Roberts and by G. W. Brindley. The relationship of this mineral to kaolinite and metahalloysite was discussed. A. Westerman and A. L. Roberts described experiments on dry and wet grinding of kaolinite and halloysite, which showed a disappearance of crystallinity on prolonged dry grinding in accordance with Law's and Page's results. A general description of the relationship of the members of this group was given by Brindley.

The second meeting was devoted to a discussion of the third subject. S. Hénin (France) and S. Caillère (France) gave an account of experiments they have been carrying out on the transformability of clay minerals. The transformation of montmorillonite to a mica-like material by the action of KOH, and of montmorillonite to a chlorite, have been achieved, but not the reverse alterations of natural micas and chlorites.

A paper by J. W. Jordan, of the Mellon Institute, Pittsburgh, was presented by R. E. Grim. It described the alteration of bentonite to a condition in which it is compatible with liquid amines. Thixotropic organic gels have been prepared in this manner.

In the last session P. Gallitelli (Italy) described the formation in nature of a kaolinitic clay (containing some mica) from diabase. Experiments on the decomposition of diabase on a laboratory scale, by the percolation of CO_2-charged water, both at normal and elevated temperature and pressure, have shown the same minerals to be formed.

D. M. C. MacEwan described the formation in a Scottish soil derived from norite of a trioctahedral montmorillonite, by alteration of flakes of a biotitic mineral. The montmorillonite occurs as stable secondary aggregates, which are pseudomorphs after the original material, and account for the high base exchange capacity of the sand and silt.

J. E. Hemingway and G. W. Brindley described the occurrence of dickite as a replacement mineral in Middle Jurassic rocks of N.E. Yorkshire, an occurrence which they consider invalidates the view that dickite is necessarily of hydrothermal origin, and indicates its migration in solution.

All the papers gave rise to lively discussion, and the exchange of views was universally felt to be valuable. Considering the specialized nature of the subject-matter, the meetings were well attended. The Chairmen at the various meetings were as follows :—

First Session . Dr. G. W. Brindley (Chairman of the Clay Minerals Group) and Dr. S. Hénin (France).

Second Session . Professor R. E. Grim (U.S.A.) and Professor J. J. de Lange (Netherlands).

Third Session . Dr. W. Campbell Smith (President of the Mineralogical Society) and Dr. J. S. Hosking (Australia).

ANNOUNCEMENT

UNIVERSITY OF LONDON : SPECIAL UNIVERSITY LECTURES IN GEOLOGY

The Academic Registrar announces that two lectures will be given at University College (Gower Street, W.C. 1) by PROFESSOR G. DELÉPINE at 5.30 p.m. on 8th and 10th March, 1949. Admission free, without ticket.

Lecture 1 : Comparative Stratigraphy of the Carboniferous Marine Formations in N.W. Europe and Mediterranean Area.

Lecture 2 : Movements of the late Palaeozoic Seas—Devonian and Carboniferous—in W. Europe and N. Africa.

Crozzle and Hussle

By F. Wolverson Cope

Abstract

Description of an intraformational contorted shale in the Middle Coal Measures of the Potteries Coalfield. The contorted bed occurs immediately below the Winpenny Coal in thin argillaceous measures between thick sandstones. It shows strongly slickensided contacts, and consists of black carbonaceous shale, folded, sheared, and burnished. Deformation is ascribed to shearing stresses operating during folding. This shale is called "hussle" by the miners, whilst a similarly contorted, but non-carbonaceous, shale was termed "crozzle" by old miners of the Staffordshire–Derbyshire moors.

BREVITY has dictated the somewhat grotesque and possibly facetious looking title for this article dealing with certain intraformational contorted rocks which occur at several horizons in the Upper Carboniferous of North Staffordshire. Both crozzle and hussle are terms which have been borrowed from the old miners' terminology still considerably used in that area, and there is much to be said for the retention of one or both words as concise descriptive terms.

It is perhaps both interesting and of some significance that such special terms should, in the past, have been coined for intraformational contorted argillaceous rocks in an area showing some intensity of folding like the North Staffordshire coalfields, whereas no equivalent terms appear to have been used in the relatively unfolded but equally long-worked South Lancashire Coalfield.

The Millstone Grit and Lower Coal Measures of the Southern Pennines area consist of a rhythmic or cyclic sequence of sandstone or grit, seat-earth, coal, marine shale, and non-marine shale in ascending order, but it is only in the Millstone Grit that the marine phase of the cycle is normally represented. In the Lower Coal Measures, and to an even greater extent in the lower part of the Middle Coal Measures, the average cyclothem is incomplete. Nevertheless, the general result of this type of sedimentation is an alternating succession of thick sandstones or grits, and shales or mudstones of varying lithology.

In those regions where these formations have been compressed into moderately acute folds of considerable amplitude and wavelength, such as the Goyt Trough or Syncline to the west of Buxton, and the Potteries Syncline which includes the main coalfield of North Staffordshire, distinct beds of cleaved, brecciated, and contorted shale occur within the argillaceous formations. These beds ranging in thickness from about ½ inch to 3 feet, are under and overlain by normally bedded shales. These peculiar rocks have recently been studied on both the western and eastern limbs of the Goyt Syncline (Cope, 1946 A),

where it was demonstrated that the beds of contorted shale are remarkably constant in the horizons at which they occur, and that the contacts of the contorted beds, as they may briefly be termed, are normally clear-cut and plane, and either highly polished or slickensided in the direction of formational dip.

Each bed consists of non-carbonaceous blue or grey strongly fissile shale, and frequently exhibits numerous small, often acute, folds within the confines of its parallel contacts. The axial planes of such folds are inclined in the direction of formational dip, but at an angle in excess of the latter. The most conspicuous large scale structure in the contorted beds, however, consists of a succession of sigmoidally curved planes of shear. Each shear-plane is inclined in the direction of formational dip, though at a higher angle, and the curving ends merge into the strongly slickensided contacts of the contorted bed. Each surface of shear is markedly slickensided, grooved or fluted, in the direction of dip.

A tectonic origin was ascribed to the contorted beds of the Goyt Trough, the small folds being interpreted as drag folds and the shear planes as fracture cleavage. It was suggested that the contorted beds mark the main horizons of bedding-plane-slip, and are due to the concentration at the least competent horizons of the shearing stresses resolved from the regional folding of an alternating series of competent and incompetent strata.

The constancy of horizon of the contorted beds, at least over the limited area occupied by the outcrop of the Millstone Grit and Lower Coal Measures in the Goyt Trough, is a remarkable character which is to be linked with a parallel uniformity of lithology at any particular horizon over the same area.

The writer recently met an aged inhabitant of Orchard Common, Axe Edge (North Staffordshire portion) who stated that his grandfather worked in the old coal pits in that area. The coal there worked was that occurring a short distance below the *Gastrioceras cancellatum* marine band, and it appears that the well-marked contorted bed lying just above the marine band (Cope, 1946 A, p. 144) was well known to these old miners. They used the position of the contorted bed as an index to the depth to coal during the operation of shaft-sinking, maintaining that the coal was to be found 11 yards below the contorted bed. Owing to the peculiar structure of this particular bed (here 1 ft. 8 in. thick), the excavation of which by pick and spade would undoubtedly present considerable difficulty, they called it the " crozzly bed ", or the contorted shale composing it " crozzle ".

This constancy of horizon did, in the early stages of the Goyt Trough investigations, suggest that the contortions might be due to contemporaneous or pene-contemporaneous subaqueous sliding.

However, the markedly slickensided contacts of the contorted beds together with the precise relationship existing between the attitude of the internal structures and the dip and strike of the enclosing strata, clearly ruled out this possibility and pointed to a tectonic origin. Nevertheless, some critics have suggested that the material composing each contorted bed had originally slumped, and that subsequently, during the folding, the slickensiding and shearing had been superimposed. Such a theory of dual origin would perhaps be more difficult to prove than to disprove.

It is thought, however, that this possibility can be eliminated for the following reasons, amongst others. First, the drag folds or main contortions bear the same intimate relationship in their attitude, to the general dip and strike, as do the shear-planes, and consequently it is difficult to escape from the conclusion that both included structures are equally related to the folding.

Secondly, it is significant that many of the contorted beds occur closely associated with marine horizons. In several cases, a contorted bed rests directly upon the fossiliferous shales of a marine band. Of the European Upper Carboniferous sedimentation it can be asserted with some confidence that during those times marked by the formation of marine bands the bottom receiving the sediments was, to all intents and purposes, horizontal over very extensive areas. Frequently this substratum was a coal seam. Only by the existence of vast areas of quasi-horizontal sediments can truly widespread marine incursions giving remarkably uniform conditions be envisaged. One example, taken almost at random, will suffice for illustration. In the Goyt Trough the marine band characterized by *Gastrioceras cumbriense* Bisat, which lies within the dominantly argillaceous sediments between the Shining Tor Grit (Holcombe Brook Grit or Huddersfield White Rock) and the Danebower Grit (Rough Rock) has a bed of contorted shale resting directly upon it. The *G. cumbriense* marine incursion was so widespread, and apparently of such strict contemporaneity, that the surface of the sediments over which this incursion took place must have been horizontal. After the deposition of a thickness of marine mud and organic remains sufficient to produce, after compaction 2 or 3 inches of shale, the thickness shown by this band throughout the Southern Pennines, it is most unlikely that the upper limit of sediment could have departed from a quasi-horizontal position. Under such a relatively stable and uniform environment, subaqueous sliding of the immediately succeeding sediments could not have been initiated.

In the Goyt Trough area it is difficult to study or compute the relative amount of bedding-plane-slip which may have occurred at various horizons during the folding of an argillaceous formation separating two thick grits. In the shale formation between any two

grits, however, at least one contorted bed is present and this would appear to mark the horizon of the major bedding-plane-slip.

In the further example, described below, from the Middle Coal Measures of the Potteries Coalfield, the competent members are close together, the whole section is clearly and frequently exhibited in underground exposures, both on dip and strike faces and in the roof of the workings, and the selection of horizon at which major bedding-plane-slip occurred is therefore of considerable interest.

A Contorted Bed in the Middle Coal Measures of North Staffordshire

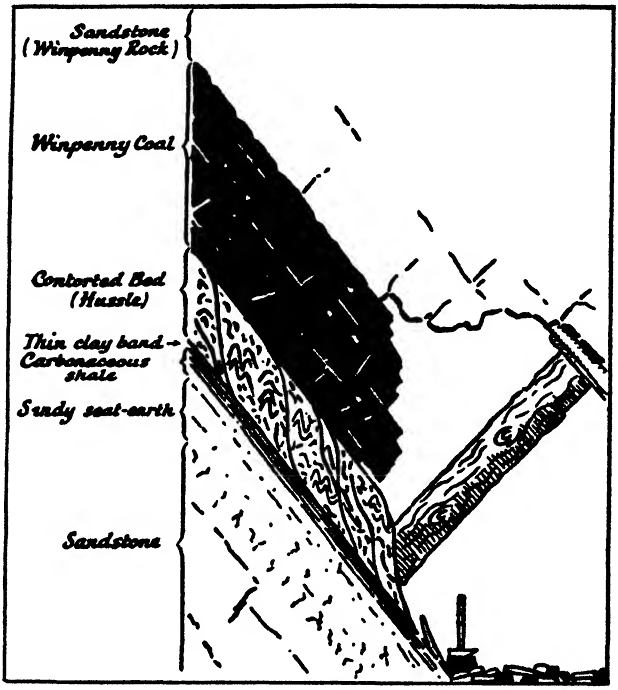
In the Biddulph, or northern, area of the Potteries Coalfield, the King Coal has been adopted, on palaeontological and stratigraphical grounds, as the base of the Middle Coal Measures (Cope, 1946 B, p. 84). Some 500 feet above the King is a good workable seam known as the Winpenny. This part of the Coal Measures succession includes a number of fairly thick sandstones. The Winpenny lies immediately below a thick sandstone (Winpenny Rock), and rests upon a few feet of shale and seat-earth which surmount a lower sandstone.

In the vicinity of Biddulph, the Potteries Syncline is a distinctly asymmetric fold with considerable amplitude and appreciable southerly pitch. The measures on the steeper western limb dip towards the east-south-east at an angle averaging 50°. Situated on this western limb and about one mile to the west of Biddulph village is the Hayhill (Winpenny) Colliery of the North Midland Coal Company. Here the Winpenny Coal is worked by means of a footrail or day-eye, which comprises a haulage road driven in the coal, dipping at 55°, from the outcrop and from which working levels are driven off on each side. Working proceeds very much on the lines of stoping in a metalliferous vein. The main haulage level now lies at a considerable distance from the outcrop. Owing to the high dip and relative thinness of the coal (2 ft. 9 in. to 3 ft.), the mine roads and working places show extensive sections of the coal and the measures lying immediately above and below.

The section depicted in Text-fig. 1 was measured in one of the higher levels of the mine and may be taken as typical.

The lowest bed exposed is a fairly massive grey sandstone with a ganister-like top containing *Stigmaria* sp. The upper surface of this is somewhat irregular, and on to it is welded a rather hard dark grey sandy seat-earth about 1 ft. thick, containing a great deal of carbonaceous material. The seat-earth passes upwards almost imperceptibly into a finely laminated highly carbonaceous black shale some 6 inches thick. This shale, which is rather greasy to the touch, contains *Sigillaria* spp. and numerous large stigmarian roots. Its

laminae are quite undisturbed, but its upper surface exhibits an almost mirror-like polish and shows slickensides running in the direction of the dip of the beds. Resting upon this very conspicuous polished bedding surface is a 1 in. band of soft grey clay. The succeeding bed is of finely laminated black carbonaceous shale, similar to the black shale just above the seat-earth in general lithology, but showing most intricate folding and shearing. In North Staffordshire this type



TEXT-FIG. 1.—Sketch of contorted bed beneath coal seam at Hayhill Colliery, near Biddulph, North Staffordshire.

of shale is known as *hussle*. This bed of hussle is 1 ft. 6 in. in thickness, and both its upper and lower contacts are beautifully polished and slickensided, the striations running in the direction of regional dip. Throughout the mine this bed shows extraordinarily perfect examples of small sub-acute folds, frequently only an inch or so in amplitude and wavelength. Without known exception the axial planes of these folds are inclined in the direction of stratal dip. In addition the bed is broken by numerous sigmoidally curved shear-planes which are strongly grooved and striated and dip in the direction of stratal dip but at an angle higher than the latter.

The (upper) contact of the contorted bed with the Winpenny Coal is conspicuously polished and slickensided in the direction of dip, and

considerable bedding-plane-slip has obviously occurred at this horizon. The seam itself is 2 ft. 10 in. thick and yields a good proportion of fairly large coal. The coal is succeeded by the Winpenny Rock which is a rather massive fine-grained sandstone, and the coal-sandstone contact is a closely welded one, no evidence of differential movement between the sandstone and coal being obtainable. In point of fact, it can be said that no slip has taken place at this horizon, for the sandstone-coal contact is slightly irregular, the sandstone descending to fill original shallow depressions in the top of the coal. There is no suggestion of a plane of movement within the coal at or below the base of these irregularities.

It would appear, therefore, that during folding the coal moved as though it were a corporate part of the overlying sandstone formation. There was, however, a distinct decrease of competence across the coal-hussle junction; in fact, this was a junction between a higher competent and a lower incompetent formation, so that considerable bedding-plane-slip occurred there.

The basal sandstone also behaved as a competent bed during folding and carried with it the succeeding beds of gradually diminishing competence up to the thin clay band. These two groups of beds moved relatively in opposing directions, so that the 1 ft. 6 in. bed of hussle was subjected to a shearing couple. In this way the mirror-like and slickensided contacts and the small internal structures of the bed were produced.

In its general structure and in its relationships to the including strata this contorted bed is identical with those of the Goyt Trough. Whereas the contorted beds of the Goyt Trough consist of non-carbonaceous blue-grey shale, this contorted bed in the Middle Coal Measures is composed of highly carbonaceous shale. In each case, however, the shale is perhaps the most incompetent rock in its respective sequence.

The term hussle is still used extensively in North Staffordshire mines. It is applied to a rather greasy highly carbonaceous closely laminated shale or bass normally occurring in close association with coal seams. At least, that would appear to represent its current usage. It is most likely, however, that its original connotation was that given by Stobbs (1916), who defines hussel, hussle, or hustle as a highly slickensided carbonaceous shale (2 feet to 5 feet thick) which overlies the Bullhurst Seam [1] on the western side of the Potteries Coalfield. Unfortunately, the Bullhurst Coal is not now worked in the intensely disturbed Western Anticlinal area, so that this horizon is no longer open for examination.

[1] The Bullhurst Coal is usually about 60 feet stratigraphically above the Winpenny, the intervening strata being mainly sandstone (Winpenny Rock).

A contorted bed, or at least an horizon on which considerable bedding-plane-slip has occurred, could well have been predicted above the Bullhurst in the northern part of the Western Anticline. There, the Bullhurst Coal attains an abnormal thickness, 30 feet and over being not at all uncommon (Cowcill, 1928). The coal is surmounted by a small thickness of shales which are succeeded by a strong sandstone, and the hussle of Stobbs lies at the base of the shales.

In this connection, the writer has recently observed a contorted bed (of hussle) above the Alex Coal on an opencast coal site at Harewood Hall, near Cheadle (Staffs). The Alex Coal of Cheadle has been correlated with the Bullhurst Coal of the Potteries Coalfield (Cope, 1946 B, p. 85).

The writer is indebted to Mr. W. Owen-Jones, of the North Midland Coal Company, for facilities so readily provided during the examination of the workings at the Hayhill Colliery.

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Zones of Progressive Regional Metamorphism in the Moine Schists of the Western Highlands of Scotland

By W. Q. Kennedy

Abstract

The Moine Schists of Western Inverness-shire and North-West Argyll show a progressive increase in metamorphism when traced from the outcrop of the Moine Thrust-plane eastwards towards the central area of regional injection and migmatitization. It is possible to distinguish four zones of progressive metamorphism characterized by the development of distinctive mineral assemblages in the very subordinate, but widely distributed and highly distinctive calc-silicate granulites. The easterly increase in grade is attributed to the thermal effect of the great injection complexes, and it is suggested that the Torridonian, the Tarskavaig Moine Schists, and the Moine Schists proper merely represent successive stages in the regional metamorphism of one formation.

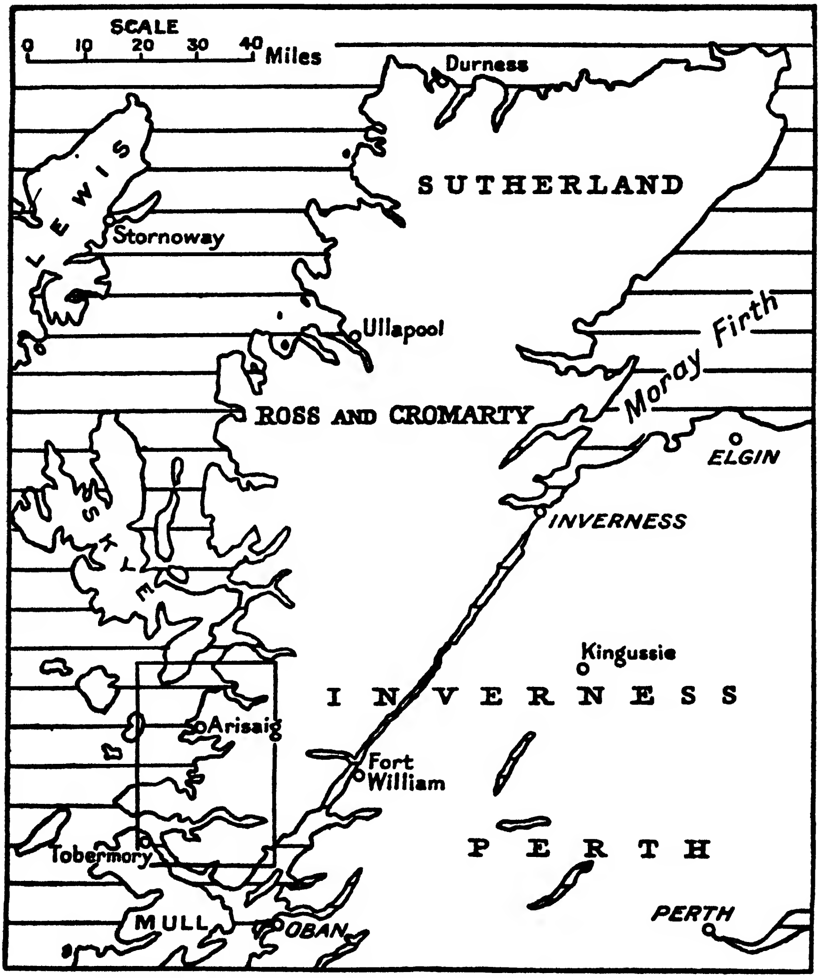
Introduction

THROUGHOUT Western Inverness-shire and North-West Argyll, the Schists of the Moine Series, which occupy most of the region between Loch Hourn and the Sound of Mull (Sheets 52 and 61 of the Geological Survey, 1-in. to the mile map of Scotland; see maps, Text-figs. 1 and 4), show a marked progressive increase in metamorphism when traced from the coastal districts eastward towards the interior of the country. This effect appears to be related to two major geological features of the region: (1) the proximity of the Moine thrust which outcrops in the Sleat peninsula of Skye immediately to the west, and (2) the highly injected state of the schists throughout the eastern part of the region. It is a matter of considerable interest, therefore, to examine these relationships in somewhat greater detail and to attempt to assess their possible significance in respect to the structural evolution of the region as a whole.

The first step involves a more detailed study of the metamorphic variation, and for this purpose it is proposed to utilize the methods initiated by Barrow (1893, 1912) more than fifty years ago, and subsequently employed by Goldschmidt (1915), Tilley (1925), Vogt (1927), Barth (1936), and others, whereby the grade of the rocks is expressed in terms of the critical index minerals which develop successively in rocks of appropriate bulk composition under conditions of advancing metamorphism. In this connection, however, the Moine Schists present certain difficulties:—

1. The rocks are predominantly siliceous types, representing metamorphosed feldspathic sandstones, and beyond a certain point tend to show no further mineralogical response to rising temperature.
2. The more sensitive pelitic schists, to which Barrow's zonal indices (chlorite, biotite, garnet, kyanite, and sillimanite) could be applied,

are subordinate or localized in their distribution, and may be entirely absent throughout wide areas. They show, moreover, an incomplete metamorphic succession in that, although the *garnet* and *sillimanite zones* are fully developed, the *kyanite zone* as such cannot be distinguished owing to the virtually complete suppression of the typomorphic index mineral *kyanite*.



TEXT-FIG. 1.—Index Map. Area of Text-fig. 4 outlined.

3. Throughout wide areas the metamorphic grade of the rocks falls within the *garnet zone* as defined in normal pelitic schists, and this zone, as Harker (1932, p. 224) has pointed out, is in any case a broad one, so that "from the first appearance of garnet a considerable further rise of temperature must take place before the appearance of any new mineral which would serve as an index to a new zone". Its width is still further increased, moreover, by the non-development of kyanite and in effect the "garnet zone" may extend right up to the sillimanite isograd. Garnet is consequently

insufficiently sensitive as an index of grade within the particular temperature ranges concerned.

For the purposes of the present paper, therefore, it is proposed to base the zonal succession on the very subordinate but rather sensitive and widely distributed, semi-calcareous, calc-silicate granulites which occur in all the typical Moine areas of Scotland, and have been regarded by Flett (1923, p. 55) as diagnostic members of the Series as a whole.

Nature and Occurrence of Calc-Silicate Granulites in the Moine Series

The rocks in question are very distinctive types which occur solely as sporadic narrow bands and lenticles, up to an inch or two in thickness, associated with the normal psammitic and striped semi-pelitic schists of the Moine Series. They are easily recognized in the field on account of their mode of occurrence,[1] dense compact nature, pale colour (grey, white, or light green), and the presence of rather characteristic, small cinnamon-coloured garnets. Flett, who has studied typical members of the group from other parts of Scotland, considers that they must represent metamorphosed, somewhat argillaceous, calcareous sandstones (Flett, 1923, p. 55), and this view is confirmed by the presence of comparatively unaltered representatives among the low-grade (early *biotite-zone*) Tarskavaig Moine Schists of the Sleat peninsula of Skye. Similar calcareous (and somewhat argillaceous) ribs and lenticles, with identical relations to the enclosing rocks, are also found in the Loch na Dal beds of the Torridonian and provide suggestive evidence as to the Torridonian age of the Moine Schists.[2]

Within the Morar area at least, the calc-silicate granulites possess a certain stratigraphical significance and appear to be confined to the Upper Psammitic, Upper Striped, and Garnetiferous Pelitic Groups of the Moine succession (Richey and Kennedy, 1939, p. 29). They have not so far been proved definitely to occur in the Lower Psammitic or Lower Striped Schists, but this limitation is of small moment as the former divisions comprise by far the greater part of the Moine

[1] It is worthy of note that the calc-silicate bands do not normally occur in contact with pelitic rocks but are mainly localized along the centres of psammitic ribs interbedded with the striped pelitic and semi-pelitic schists.

[2] The calcareous ribs and lenticles in the Loch na Dal beds of the Torridonian are quite unaltered and still retain their original clastic structure. They are seen to consist essentially of angular grains of quartz and feldspar, together with shreds of chlorite and chloritized biotite, sericite, and rather abundant carbonate. The latter occurs either as a constituent of the base or in the form of tiny veins which intersect the rock in all directions. The feldspar was found to be predominantly albite in all the cases examined.

succession and are, moreover, widely distributed throughout the area as a result of folding.

Progressive Metamorphism of the Rocks

The mineralogical characters of the calc-silicate granulites from the area under consideration vary according to locality and in relationship to the progressive easterly increase in metamorphism which characterizes the region as a whole. Various parageneses have been recognized and are set out in Table I below. Analyses of typical representatives together with certain other analyses for comparison are given in Table II.

TABLE I

Parageneses of the Calc-Silicate Granulites in the Moine Series

	1			2	3	4
	a	b	c			
Quartz	+	+	+	+	+	+
Calcite	+	+				
Zoisite	+	+	+	+		
Acid Plagioclase	+	+	+	+		
Bytownite					+	+
Biotite	+	+	+			
Hornblende		+		+	+	
Pyroxene						+
Garnet	+	+	+	+	+	+

The rocks in all cases consist essentially of quartz, together with garnet, a lime-silicate and one, or in certain transitional types, two ferromagnesian minerals. Acid plagioclase occurs only in the zoisite-bearing assemblages where it forms an important constituent of the ground mass mosaic.

Quartz and garnet are ubiquitous constituents and are present in all assemblages irrespective of grade. The garnet is the common red variety (almandine), but presumably contains a certain proportion of grossularite molecule as Barth (1936, p. 788) has shown to be the case in similar rocks from Dutchess County, New York. It forms poikiloblastic crystals which in the lower grades of metamorphism tend to develop crystal boundaries, but in the higher grades become smeared out into irregular streaks.

TABLE II

ANALYSES OF CALC-SILICATE ROCKS

	1	2	A	B	3
SiO_2 .	62·73	62·55	59·25	71·87	73·51
Al_2O_3 .	16·69	15·75	13·30	12·75	12·21
Fe_2O_3 .	0·42	1·56	0·84	0·29	0·44
FeO .	3·02	3·26	4·71	4·25	2·05
MgO .	1·09	2·88	4·20	1·07	0·59
CaO .	8·86	9·39	11·37	7·08	9·52
Na_2O .	2·88	0·93	1·73	0·33	0·21
K_2O .	0·90	1·54	2·42	0·06	0·05
H_2O+ .	0·94	0·64	0·73	0·55	0·27
H_2O- .	0·10	0·15	0·09	0·05	0·06
TiO_2 .	0·67	0·79	0·75	1·31	0·54
P_2O_5 .	0·31	0·30	0·18	0·05	0·11
MnO .	0·29	0·28	0·08	0·43	0·44
CO_2 .	0·98	tr.	0·13	n.d.	0·06
Rest .	—	0·09	0·14	—	0·02
Total .	99·90	100·11		100·10	100·08

1. Calc-zoisite-biotite-garnet granulite; (calc-silicate band) in Upper Striped Group of Moine Series, Shore N.E. side of Mallaig Harbour, Inverness-shire. C. O. Harvey, analyst. Average analysis of twenty individual bands.
2. Zoisite-hornblende granulite in Moine Series, 3/4 ml. S.W. of Glen Calvie Lodge, Ross-shire. W. Pollard, analyst, quoted from the "Geology of Ben Wyvis, etc." (Sheet 93), *Mem. Geol. Survey*, 1912, p. 45.

A. Calc-silicate gneiss, Almaaskroken, Norway. A. Röer, analyst. Quoted from V. M. Goldschmidt, "Die Kalksilikatgneise und Kalksilikatglimmerschiefer des Trondhjem-Gebiets," *Vidensk. Skr. I., Mat.-Naturv. Klasse.*, 1915, No. 10, p. 15.

B. Lime-silicate schist (hornblende-anorthite-garnet), Dutchess County, New York. E. Kluver, analyst. Quoted from T. Barth, "Structural and Petrological Studies in Dutchess County, New York, II. Petrology and Metamorphism of the Palaezoic Rocks." *Bull. Geol. Soc. Am.*, vol. 47, 1936, p. 813.

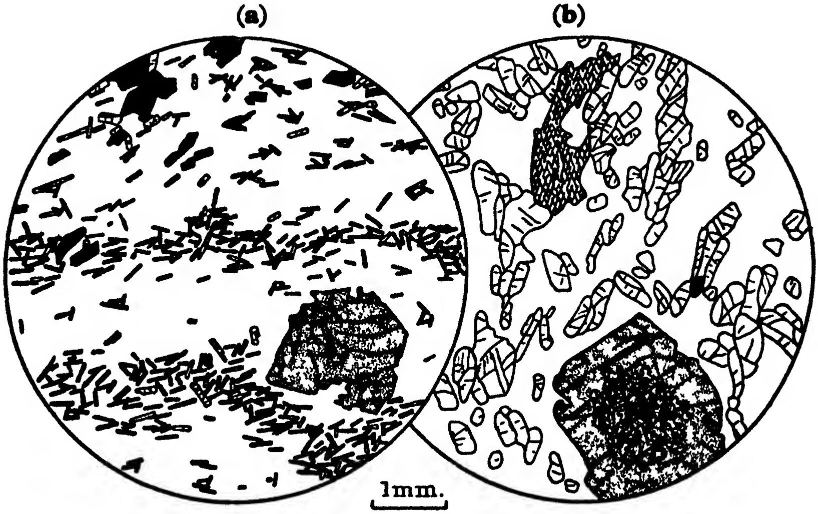
3. Pyroxene-anorthite granulite; calc-silicate band in Moine Series, Moidart district, 100 yards S. 20° W. of Dalilea Mica Prospect and 1,630 yards E. 10° S. of General Ross's Cairn. G. A. Sergeant, analyst.

The lime-silicate is either zoisite or anorthite, depending on the conditions of metamorphism; the transition from one to the other being controlled by the following reaction :—

$$2 \text{ zoisite} = 3 \text{ anorthite} + Ca(OH)_2$$

Zoisite is stable at the lower temperatures and is consistently a β variety with normal greyish interference colours and small optic axial angle. It forms either stout prismatic crystals (Text-fig. 2 (*b*)) or swarms of long thin needles (Text-fig. 2 (*a*)), which latter mode of occurrence is quite typical of the Group I assemblages (Table I), and could even be employed as a diagnostic feature of grade. Other

members of the clinozoisite-epidote group are not formed during the progressive metamorphism, but are developed locally in the high-grade assemblages where they result from retrograde reaction. *Anorthite* is confined to the high-temperature end of the metamorphic series and is present in the form of *bytownite* with approximately 85 to 90 per cent anorthite molecule (Text-fig. 3). There is no indication of gradual and progressive increase in the anorthite content of the plagioclase feldspar with advancing metamorphism, but on the contrary, the transition from albite and zoisite-bearing assemblages, on the one hand, to bytownite-bearing assemblages, on the other, appears to take place abruptly at the appropriate temperature. Potash feldspar has not been identified definitely in any of the rocks and the rôle of potassium remains obscure.



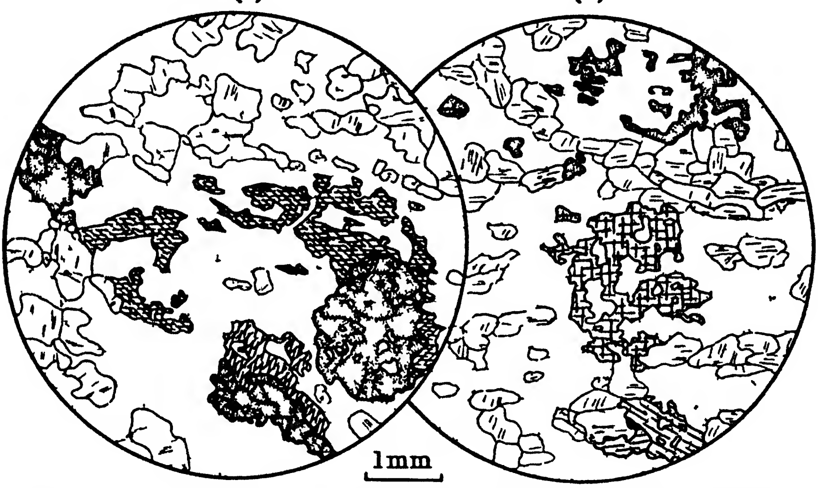
TEXT-FIG. 2.—Zoisite granulites from the Moine Series of Morar :
(*a*) Garnetiferous zoisite-biotite granulite.
(*b*) Garnetiferous zoisite-hornblende granulite.

Under different conditions of metamorphism the stable ferromagnesian mineral may be represented either by biotite, hornblende, or pyroxene. The *biotite* is a normal reddish-brown variety and is confined to the Group 1 assemblages of Table I. *Hornblende* is stable over a considerable range of temperature and is characteristic of the intermediate stages of metamorphism. It is typically a distinctive, greyish-green, only slightly pleochroic type and forms rather large, irregular, spongy crystals much penetrated by the quartz of the groundmass mosaic. In addition, bright-green, highly-pleochroic, actinolitic hornblende is found in certain of the pyroxene-bearing granulites and represents a product of retrograde reaction. Colourless, apparently highly aluminous, pyroxene is confined entirely to the high-temperature assemblages and may, as pointed out above, revert to acicular, actinolitic hornblende as a result of retrograde change.

Sphene, apatite, zircon, and magnetite are ubiquitous constituents. The structure of the rocks is granulitic or finely granoblastic, and

it is interesting to note that the grain size shows a progressive increase with advancing metamorphism. This is marked by an increase in the average diameter of quartz individuals in the ground mass mosaic, from 0·1 mm. in the Grade 1 assemblages of Table I to approximately 0·7 mm. in the Grade 4 bytownite-pyroxene-bearing types, and must involve suppression of the majority of the quartz grains and enlargement and progressive growth of a very small minority. The mechanism of the process when fully investigated should, therefore, prove to have an important bearing on the metamorphic evolution of the rocks.

It is apparent from the petrological and chemical characters of the calc-silicate granulites, that they belong to a well-defined *isochemical* series and that the differences in mineralogical composition are due



TEXT-FIG. 3.—Bytownite-granulites from the Moine Series of Morar:
(*a*) Garnetiferous bytownite-hornblende granulite.
(*b*) Garnetiferous bytownite-pyroxene granulite.

directly to differences in metamorphic environment. The observed parageneses consequently represent successive stages in the progressive metamorphism of the rocks. Consideration of the data in Table I shows, moreover, that the calc-silicate granulites from the area fall naturally into four well-defined groups or *facies* characterized by the following stable and critical mineral associations :—

Group 1 .	garnet-zoisite-acid plagioclase-biotite	
	(*biotite* + *calcite* (*zoisite*) → *hornblende*)	Reaction
Group 2 .	garnet-zoisite-acid plagioclase-hornblende	
	(2 *zoisite* → 3 *anorthite* + $Ca(OH)_2$)	Reaction
Group 3 .	garnet-anorthite (bytownite)-hornblende	
	(*hornblende* → 4 *pyroxene*)	Reaction
Group 4 .	garnet-anorthite (bytownite)-pyroxene	

These can be correlated with Eskola's standard facies as follows :—

Standard Facies. (Eskola)	Facies of Calc-silicate Granulites.
Epidote-amphibolite facies . .	Group 1 (Table I)
	„ 2 („)
Amphibolite facies	„ 3 („)
Pyroxene-hornfels facies . . .	„ 4 („)

It may be pointed out with regard to the equilibrium relationships of the rocks, that the presence of pyroxene would seem to depend not only on temperature, but also on an increase in the $\frac{CaO}{MgO}$ ratio. That such an increase has actually taken place in the case of the pyroxene-bearing assemblages may be seen from the analyses (1 and 3) in Table II where these rocks, when compared with the assemblages of lower grade, show a decrease in alkali content and a concomitant increase in the $\frac{CaO}{MgO}$ ratio. The distribution, mode of occurrence and field relationships of the calc-silicate granulites indicate that the rocks, in all cases, belong to a single isochemical series and must have been derived from essentially the same type of original material. The compositional differences are thus confined to the region of highest metamorphism and therefore the significant variations in certain chemical constituents must be attributed to actual change in the bulk composition of the rocks, effected during the process of metamorphism in the attainment of mineralogical equilibrium.

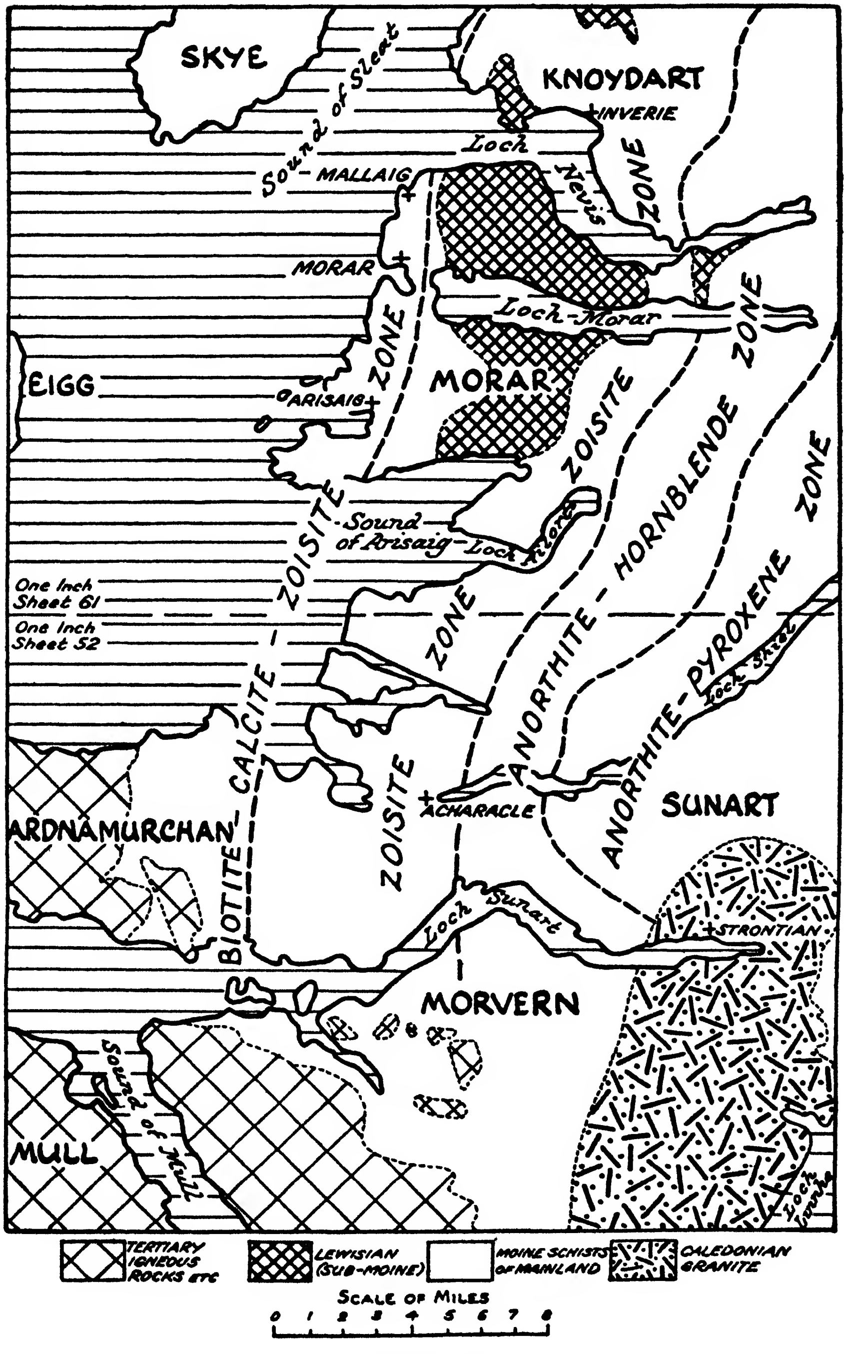
Zonal Relationships of the Moine Series Based on the Progressive Metamorphism of the Calc-Silicate Granulites

On the basis of the critical reactions, outlined above, it is possible to divide the region into a succession of metamorphic zones, each of which covers the pressure-temperature limits of one of the four mineral facies (see Zonal Map, Text-fig. 4). The zonal boundaries can be drawn with considerable precision, and it is found that the transition from one facies to another takes place abruptly, usually within a few hundred feet. Assemblages transitional between two different facies are consequently of highly restricted occurrence.

The various zones can be designated according to the leading (index) minerals or critical phases of each facies, and the following can be recognized from east to west :—

(1) Zoisite-(calcite-)biotite zone
(2) Zoisite zone
(3) Anorthite-hornblende zone
(4) Anorthite-pyroxene zone

MAP OF METAMORPHIC ZONES IN WESTERN INVERNESS-SHIRE AND N.W. ARGYLL



TEXT-FIG. 4.

This corresponds to a progressive easterly increase in metamorphic grade.

In general the zonal boundaries conform with the regional strike of the rocks, but the metamorphic zones themselves are not symmetrically disposed with respect to major folds, such as the Morar anticline, nor are they apparently influenced by the presence of inliers of older rock. There is, consequently, no simple depth relationship between the metamorphic zones and the tectonic structure. On the other hand, it is significant that the isograde which marks the zoisite-anorthite transition coincides almost exactly with the observed western limit of regional injection, as Read (1931) has also recognized in Central Sutherland. To the west of this line the rocks are normal Moine schists which show straight bedding, and in general retain all the details of their original sedimentary structures. They show little or no evidence of additive metamorphism, and convey the impression of having been metamorphosed within the garnet zone without serious intergranular movement. The Moine schists to the east of the anorthite *isograd* are in a fundamentally different condition, and are represented by coarsely crystalline injection gneisses and migmatites. Complex flowage folding, and widespread development of "boudinage" structures are characteristic phenomena and indicate intense movement of the rocks in a semi-plastic condition. Within this zone, which extends northward, southward, and eastward far beyond the limits of the area under immediate consideration, the Moine schists have been subjected to intense lit-par-lit injection and permeation by granitic material.

The metamorphic zones run parallel to the edge of this great injection complex, and there can be little doubt that they owe their development to the heat transmitted outwards from the thermal focus.

Within the interior of the injection complex the normal pelitic schists of the Moine series have been converted into sillimanite-cordierite gneisses and it is possible to locate the position of the sillimanite *isograd* with considerable precision. It is found to conform fairly accurately with the calc-silicate granulite isothermal boundaries, and to lie a short distance to the west of the pyroxene *isograd.* This provides a basis for the metamorphic correlation of the pelitic schists and calc-silicate granulites shown in table on p. 53.

As in the case of the Moine Schists generally, kyanite does not develop in the pelitic rocks of the district, and, following garnet, the first new mineral to appear with advancing metamorphism is normally sillimanite. It is not possible, therefore, to effect a complete metamorphic correlation of the calc-silicate granulites and pelitic schists on the basis of local evidence. Barth (1936, pp. 823–4) has pointed out, however, that in Dutchess County, New York, garnetiferous anorthite-hornblende granulites of the type in question are

Metamorphic Condition of Moine Schists	Uninjected		Injected	
Mineralogical Reaction in Calc-Silicate Granulites	Zoisite ——→ Anorthite Biotite → Hornblende		Hornblende → Pyroxene	
Zones based on Calc-Silicate Granulites	Zoisite-(Calcite)-Biotite Zone	Zoisite Zone	Anorthite-Hornblende Zone	Anorthite-Pyroxene Zone
Equivalent Zones in Normal Pelitic Schists	*Garnet Zone*		(*Kyanite Zone*)	*Sillimanite Zone*
Variation in metamorphic Environment	Temp. increase ——→			

isofacial with kyanite schists, and anorthite-pyroxene granulites with sillimanite gneisses. It may be assumed, therefore, that the position of the missing kyanite-zone in the Moine Schists is indicated by the anorthite-hornblende assemblages.

These results are in essential agreement with those obtained by Goldschmidt from the Trondhjem region (Goldschmidt, 1915, pp. 5–8), where in the development of typical calc-silicate gneisses from the semi-calcareous members of the Lower Palaeozoic Gula Group, the following stages could be recognized :—

Biotite zone	No lime silicates found.	Quartz - muscovite - biotite - calcite phyllites.
Garnet zone (including kyanite and sillimanite zones of Barrow)	(*a*) Development of members of clinozoisite - epidote group + almandine garnet.	Garnetiferous epidote-biotite granulites.
	(*b*) Development of hornblende.	Garnetiferous epidote-hornblende granulites.
	(*c*) Development of plagioclase at the expense of clinozoisite-epidote.	Plagioclase-hornblende granulites.
	(*d*) Development of pyroxene-at the expense of hornblende.	Plagioclase-pyroxene granulites.

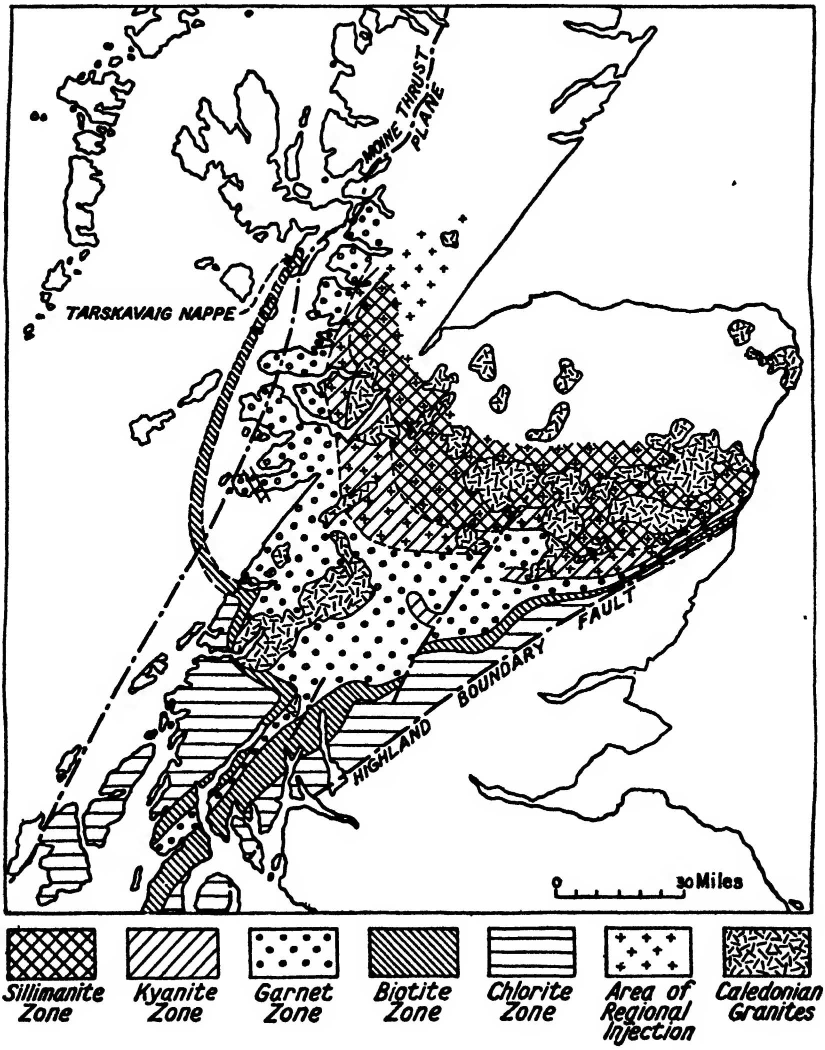
Despite significant differences in mineralogical and chemical composition this case provides an interesting parallel to the Moine Schists and confirms the usefulness of such semi-calcareous rocks as indices of grade in studies of progressive regional metamorphism.

Interpretation of the Results

In attempting to establish the significance of the zonal relationships discussed in the preceding sections, consideration must be given to

the fact that the area under investigation merely constitutes part of a much wider region of metamorphism which extends throughout the Highlands from the outcrop of the Moine Thrust Plane south-

GENERAL THERMAL MAP OF THE HIGHLANDS.



TEXT-FIG. 5.

eastwards to the Boundary Fault. Within this region the crystalline schists of the Moine and Dalradian Series show extreme variation with respect to metamorphic grade, as may be seen from the general zonal map (Text-fig. 5). In this map, which incorporates all the available zonal data, a correction has been made for the 65 miles of lateral displacement along the Great Glen Fault (Kennedy, 1946),

and the metamorphic zones appear in their true pre-fault relationships. The areas of regional injection and the main Caledonian granite masses are also shown.

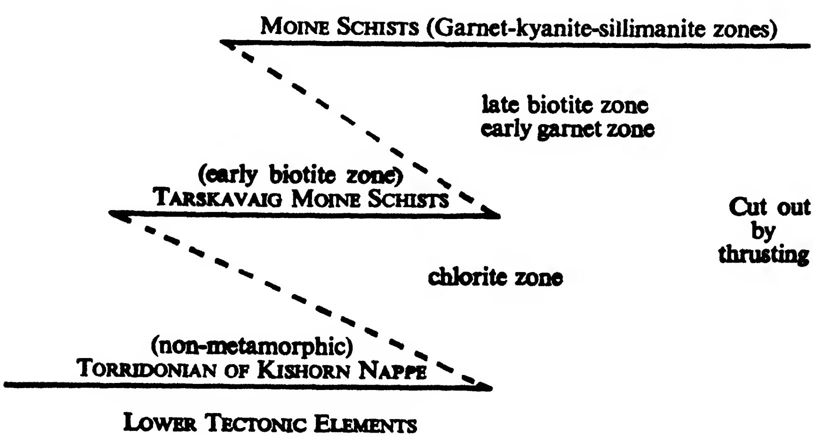
Consideration of the map leads to the recognition of the following significant features :—

(1) The inner (high temperature) kyanite and sillimanite *isograds* conform to the outer limit of central regional injection.

(2) The outer (low temperature) biotite and garnet *isograds*, on the other hand, are essentially parallel to the boundary fractures of the Highlands (Moine Thrust and Highland Boundary Fault).

These relationships can be readily explained if, following Barrow (1912), we attribute the metamorphism of the Highlands to the thermal influence of regional injection and relate the marginal decrease in metamorphism to distance from the thermal focus combined with fracture along the edges of the crystalline mass and outward thrusting in response to post-crystalline pressure.

Within the area with which the present paper has mainly been concerned, three formations, the Moine Series, the Tarskavaig Moine Series, and the Torridonian Series come together in South-East Skye, where they occupy different tectonic units, and form a series of superimposed nappes, piled one upon the other, in an ascending order of increasing metamorphism. The general structural and metamorphic relationships of these nappes are shown diagrammatically below :—



The contacts are thrust contacts, but despite the tectonic discordance one can clearly recognize that the westerly decrease in metamorphism of the Moine nappe (Text-fig. 4) continues in the lower tectonic elements. By straightening out the thrust tectonics we find that the three formations fall into line as follows :—

Torridonian of Kishorn Nappe		Tarskavaig Moines		Moine Schists
non-metamorphic	chlorite zone	early biotite zone	late biotite zone ↓ early garnet zone	garnet zone ↓ kyanite zone ↓ sillimanite zone

The distinctions between the Torridonian, the Tarskavaig Moine Schists, and the Moine Schists proper are then seen to depend merely on an original westerly decrease of regional metamorphism affecting one great formation, combined with the fracturing and thrusting of the rocks along the edge of the crystalline area, and the consequent tectonic elimination of stages in the metamorphism.

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Types and figured specimens of Lower Palaeozoic Trilobites in the University Museum, Oxford

By JAMES M. EDMONDS

ABSTRACT

Seventy specimens of trilobites are listed and reference is made to the works in which they were figured and described. Many of them were originally in private collections which have been deposited in the University Museum since the time of the publication. The specimens have been allotted numbers under a scheme of registration which it is intended should eventually incorporate the whole of the research and reference palaeontological collections under the care of the Professor of Geology at Oxford.

INTRODUCTION

AN attempt is being made to catalogue the types and figured specimens in the collections of the Department of Geology at Oxford, as a first step towards the registration of the very large and valuable palaeontological collection which is under the care of the Professor of Geology and Palaeontology. It is hoped by this means to provide a record from which those engaged in palaeontological research can learn what material is available and, at the same time, to make the material more readily accessible for study.

As described in R. T. Gunther's *Early Science in Oxford*, the earliest collection of fossils in Oxford belonged to the Ashmolean Museum, and was founded on specimens presented by Martin Lister in 1685, and by Robert Plot in 1690. Edward Lhwyd, who followed Plot as Keeper of the Museum in 1691, was responsible for the first catalogue, but of the specimens listed in his *Lithophylacii Britannici Ichnographia* (1699) only two have been recognized as being still preserved in our present collections. Gunther also recorded his discovery in 1931 of a collection of fossils in Oriel College, which were labelled in the handwriting of Lhwyd and bore serial numbers, names, and localities agreeing with the details printed in the catalogue. He concluded, however, that they were duplicate specimens belonging to Richard Dyer, a friend of Lhwyd and a Fellow of Oriel.

The Collections have twice undergone removal since the eighteenth century, once in 1830, when William Buckland was Reader in Geology, and again in 1860, when his successor, John Phillips, was responsible for their transfeı to the newly-built University Museum. At the same time they were greatly enriched by the private collections of these two Professors.

Soon after the removal in 1860, Phillips began the preparation of a catalogue of the fossils, being assisted in the work of their identification by Robert Etheridge, but the work is incomplete and lapsed after Phillips' death, and for three-quarters of a century no detailed record

appears to have been kept of the numerous collections, many of them of great interest, which have been added to the Museum by donation or purchase. There is, however, a manuscript list of types recognized by Miss M. Healey during the reorganization at the beginning of the present century, and this list has been of great value in the present work.

Once again, a transfer of the collections is taking place to a new Department of Geology, and Professor J. A. Douglas, recognizing the importance of seizing an opportunity which is not likely to occur again, has asked me to undertake the work of registration. The system which has been adopted is based on, and is very similar to, that in use at the Sedgwick Museum, Cambridge, and I am indebted to the Curator, Mr. A. G. Brighton, foı his advice and explanation. Mr. W. E. Howarth, of the National Museum of Wales, kindly gave me information about the methods adopted in cataloguing at that Museum.

The first list to be completed is that of the Trilobites, and although it does not claim to be exhaustive, it is a record of what has so far been discovered, and may be of assistance to workers in this group by indicating the various collections which are available at Oxford for study. The method of presentation resembles that given by Dr. C. J. Stubblefield in *Summary of Progress of the Geological Survey for 1936—Part II*, pages 27–51. If the current name of a fossil differs from that originally given the new name is printed in heavy-faced type. Emendations and additions to the original notices of the stratigraphical horizon and locality of specimens are placed in square brackets, and the usual abbreviations are used : H. for Holotype, L. for Lectotype, and S. for Syntype. The registered number of the specimen is placed within square brackets at the bottom right-hand of each entry.

I wish to thank Professor J. A. Douglas for the opportunity to begin this work, and for his continued encouragement, and I would also like to express my indebtedness to Dr. C. J. Stubblefield, who kindly read through the list and directed me to literature which I had missed.

CAMBRIAN

Agnostus **cyclopyge** Tullberg 1880. Upper Lingula Flags.
Figured Lake 1906, pl. ii, fig. 21, p. 27 ; mentioned Lake 1946, p. 339. Species is genotype of **Pseudagnostus** Jaekel 1909.
White-leaved Oak, Malvern Hills, Herefordshire. [A1]

Bailiella lyelli (Hicks 1871), see under *Conocoryphe lyellii.*

Conocoryphe **lyellii** Hicks 1871. [Solva Beds, Middle Cambrian.]
Figured Hicks 1871, pl. xvi, fig. 6, p. 399. Species referred to **Bailiella** Matthew 1885, Resser 1936, p. 17 ; Lake 1940, p. 277.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. S. [A10]

? **Ctenopyge bisulcata** (Phillips 1848), see under *Olenus pauper.*

Ctenopyge teretifrons (Angelin 1854). Upper Lingula Flags.
Figured Lake 1913, pl. x, fig. 10, p. 88.
" Malvern," [? Herefordshire]. [A6]

Eodiscus punctatus (Salter 1864), see under *Microdiscus punctatus.*

Microdiscus **punctatus** Salter 1864. Menevian.
Figured Lake 1907, pl. iii, figs. 13, 17, 17a, p. 36. Species referred to **Eodiscus** Hartt MS. Walcott 1884, Howell 1925, p. 123 ; Lake 1946, p. 339.
fig. 13. Dwrrhyd, near Solva, Pembrokeshire. [A2]
fig. 17. ditto [A3a]
fig. 17a. ditto [A3b]

Olenus pauper Phillips 1871. Upper Cambrian.
Figured Phillips 1871, diagram xvii, fig. 4,[1] p. 68. Referred to ? *Sphaerophthalmus flagellifer* Angelin 1854, Groom 1902b, p. 103 ; to ? **Ctenopyge bisulcata** (Phillips 1848), Lake 1913, p. 81.
South Malverns, [Herefordshire]. Phillips Coll. H. [A9]

Paradoxides harknessi Hicks 1871. [Solva Beds, Middle Cambrian.]
Counterpart of specimen (Sedgwick Mus. A1085) figured Hicks 1871, pl. xv, fig. 9, p. 399, and refigured Lake 1935, pl. xxvii, fig 3, p. 217.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. [A179]

Paradoxides sedgwicki (Hicks 1871), see under *Plutonia sedgwickii.*

Plutonia sedgwickii Hicks 1871. [Solva Beds, Middle Cambrian.]
Figured Hicks 1871, pl. xv, fig. 2, p. 399 ; referred to **Paradoxides sedgwicki,** Lake 1935, pl. xxxi, fig. 10, p. 221, where a wax cast (Sedgwick Mus. A1078) of an artificial intaglio of this specimen is figured.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. S. [A173]

Plutonia sedgwickii Hicks 1871. [Solva Beds, Middle Cambrian.]
Counterpart of specimen (Sedgwick Mus. A1077) figured Hicks 1871, pl. xv, fig. 3, p. 399, and refigured Lake 1935, pl. xxxi, fig. 8, p. 221, where referred to **Paradoxides sedgwicki.**
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. S. [A11]

Pseudagnostus cyclopyge (Tullberg 1880), see under *Agnostus cyclopyge.*

[1] Figure is reversed.

Sphaerophthalmus major Lake 1913. Upper Lingula Flags.
Figured Lake 1913, pl. viii, figs. 12, 13, p. 77.
fig. 12. Malvern Hills, Herefordshire. S. [A4]
fig. 13. ditto S. [A5]

TREMADOCIAN

Acanthopleurella grindrodi Groom 1902. Bronsil Shales, Tremadoc.
Figured Groom 1902a, text-figs. 2, 3, p. 70 ; refigured and referred to *Shumardia pusilla* (Sars 1835), Lake 1907, pl. iv, fig. 3, pp. 40, 42 ; opinion of Stubblefield and Raw given that Groom's name should stand, Lake 1946, p. 341. According to Groom 1902a, p. 70, specimen was referred to *Conophrys salopiensis* Callaway 1877, pp. 660, 667. **Genoholotype.**
Southern Malverns, [Herefordshire]. Grindrod Coll. H. [A7]

Acanthopleurella grindrodi Groom 1902. Bronsil Shales, Tremadoc.
Figured Groom 1902a, text-fig. 4, p. 70 ; see also references above.
Southern Malverns, [Herefordshire]. Grindrod Coll. P. [A8]

Asaphellus homfrayi (Salter 1866), see under *Asaphus homfrayi.*

Asaphus (*Isotelus ?*) **homfrayi** Salter 1866. Tremadoc Slates.
Counterpart of the specimen (Sedgwick Mus. A1266) figured Salter 1866a, pl. xxiv, fig. 6, p. 165, and Salter 1866b, pl. viii, fig. 11, p. 311. Species is the genotype of **Asaphellus** Callaway 1877.
Under the Garth, near Tremadoc, [Carnarvonshire]. Ash Coll. ex Homfray Coll. Counterpart of S. [A16]

Niobe homfrayi Salter (?). Bronsil Shales.
Figured Groom 1902b, text-fig. 31, p. 125. Lake 1942, p. 331, says " not *Niobe* (*Niobella*) *homfrayi* Salter ".
Southern Malverns, [Herefordshire]. ? Grindrod Coll. [A30]

Niobe (*Ptychocheilus*) ? sp. Bronsil Shales.
Figured Groom 1902b, text-fig. 30, p. 122. " Too poor for accurate determination ", according to Reed 1931, p. 471.
[South] Malvern[s, Herefordshire]. ? Phillips Coll. [A203]

Platypeltis sp., cf. *croftii* Callaway. Bronsil Shales.
Figured Groom 1902b, text-fig. 29, p. 122. Lake 1942, p. 315, says " cannot belong to this [*Platypeltis*] genus ".
White-leaved Oak, Malvern [Hills, Herefordshire]. ? Grindrod Coll. [A28]

Tomaculum problematicum Groom 1902. Bronsil Shales.
Figured Groom 1902b, text-figs. 32, 33, 34, 35, p. 126. **Genoholotype.**
fig. 32. [South] Malvern[s, Herefordshire]. ex G. E. Mackie Coll. S. [A34]

figs. 33, 34. [South] Malvern[s, Herefordshire]. Mackie Coll. S. [A35]
fig. 35. ditto ditto S. [A33]

ORDOVICIAN

Ásaphus (*Basilicus ?*) **radiatus** (Salter 1846). [Ashgillian.]
Figured Salter 1866, pl. xviii, fig. 1, p. 157 ; referred to **Ptychocheilus** Nova'k 1883, Reed 1931, p. 465.
Berwyn Mountains, [Merioneth].[1] ex Blunt Coll. [B2]

Eohomalonotus quadratus (Hicks 1873), see under *Neseuretus quadratus.*

Neseuretus **quadratus** Hicks 1873. [Arenig.]
Figured Hicks 1873, pl. iii, figs. 12, 24, p. 45. Species referred to *Homalonotus* (*Brongniartia* sens. lato) Reed 1918, p. 319 = **Eohomalonotus** op. cit., p. 231.
fig. 12. Ramsay Island, or Tremanhire, St. David's, Pembrokeshire. Hicks Coll. S. [B9]
fig. 24. ditto ditto ? S. [B10]

Nieszkowskia unicus (Wyville Thomson 1857), see under *Staurocephalus ? unicus.*

Niobe **menapiensis** Hicks 1873. [Arenig.]
Figured Hicks 1873, pl. iv, figs. 3, 4, p. 46 ; referred to *Asaphellus* Callaway 1877, Brögger 1896, p. 61 ; to *Hemigyraspis* Raymond 1910, p. 41 ; to **Ogyginus ?** Raymond 1912, Reed 1931, p. 461.
fig. 3. St. David's, Pembrokeshire. Hicks Coll. S. [B6]
fig. 4. ditto ditto S. [B7]

Niobe solvensis Hicks 1873. Arenig.
Figured Hicks 1873, pl. iv, fig. 10, p. 47 ; referred to *Asaphellus* Callaway 1877, Brögger 1896, pp. 43, 47 ; to **Niobe** (?) Reed 1931, p. 471.
Ramsey Island or Tremanhire, St. David's, Pembrokeshire. Hicks Coll. S. [B8]

Ogyginus ? menapiensis (Hicks 1873), see under *Niobe menapiensis.*

Ptychocheilus radiatus (Salter 1846), see under *Asaphus* (*Basilicus ?*) *radiatus.*

Sphaerocoryphe thomsoni Reed 1906, see under (a) *Staurocephalus* (*?*) *unicus*, (b) *Staurocephalus* sp.

Staurocephalus (*?*) *unicus* (Wyville Thomson 1857). [Balclatchie Group.]
Figured Salter 1865, pl. vii, figs. 22a, 22b, 22c, p. 86 ; referred to *Cheirurus* (**Sphaerocoryphe**) **thomsoni** Reed 1906, p. 146.

[1] Note associated with specimen gives the locality as " N. Wales, probably near Bala or Corwen ".

Penwhapple Glen or Burn, Ayrshire. ex Wyville Thomson Coll. [probably composite from B4 and B5]

Staurocephalus (*?*) *unicus* (Wyville Thomson 1857). [Balclatchie Group.]
Figured Salter 1865, pl. vii, fig. 23, p. 86; referred to *Cheirurus* (**Nieszkowskia**) **unicus** (Wyville Thomson) Reed 1906, p. 142.
Penwhapple Glen or Burn, Ayrshire. ex Wyville Thomson Coll. [B3]

Staurocephalus sp. (*Staurocephalus nodulosus* Salter Ms.). Drummock Group.
Figured Salter 1865, pl. vii, fig. 25, p. 87. Should be referred to **Sphaerocoryphe thomsoni** Reed 1906.
Girvan, Ayrshire. ex Wyville Thomson Coll. [B1]

ORDOVICIAN OF PERU

Asaphus sp. Llanvirnian.
Figured Douglas 1933, pl. xxix, fig. 7, p. 345.
Bed B, Yuscamayo River, Peru. Douglas Coll. [BU9]

? Homotelus sp. Llanvirnian.
Figured Douglas 1933, pl. xxviii, fig. 10, p. 345.
Bed C, Yanahurco River, Peru. Douglas Coll. [BU1]

Homotelus sp. Llanvirnian.
Figured Douglas 1933, pl. xxviii, figs. 11, 12, 13, 14, p. 344.

figs. 11, 12.	Bed C, Yanahurco River, Peru.	Douglas Coll	[BU2]
fig. 13.	ditto	ditto	[BU3]
fig. 14.	ditto	ditto	[BU4]

Triarthrus aff. **fischeri** Billings emend. Bulman 1931. Llanvirnian.
Figured Douglas 1933, pl. xxix, fig. 6, p. 345.
Bed C, Yanahurco River, Peru. Douglas Coll. [BU8]

Triarthrus sp. Llanvirnian.
Figured Douglas 1933, pl. xxix, figs. 3, 4, 5, p. 345.

fig. 3.	Bed A, Yuscamayo River, Peru.	Douglas Coll.	[BU5]
fig. 4.	ditto	ditto	[BU6]
fig. 5.	Bed B, Yuscamayo River, Peru.	ditto	[BU7]

Trinucleus sp. Llanvirnian.
Figured Douglas 1933, pl. xxix, fig. 8, p. 346.
Bed C, Yanahurco River, Peru. Douglas Coll. [BU10]

SILURIAN

Acaste downingiae (Murchison 1839) var., see under (a) *Phacops constrictus*, (b) *Phacops downingiae*.

Dalmanites nobilis (Thomas 1900), see under *Phacops* (*Dalmania*) *nobilis*.

Dalmanites vulgaris (Salter 1864), see under (a) *Phacops caudatus* var. *a vulgaris*. (b) *Phacops caudatus* var. *β*, *tuberculato-caudatus*.

Deiphon forbesi Barrande 1850. Wenlock Shale.
Figured Salter 1865, pl. vii, figs. 1a, 1b, 1c, 2, p. 88 ; referred to var. **barrandei** Whittard 1934, p. 513.
figs. 1a, 1b, 1c. " Malvern," [Herefordshire]. Grindrod Coll. [C19]
fig. 2. ditto ditto [C20]

Deiphon forbesi Barrande 1850 var. **barrandei** Whittard 1934. Wenlock Shale.
Figured Whittard 1934, pl. xvi, figs. 1, 4, p. 513.
fig. 1. West of the Malvern Hills, Herefordshire. Grindrod Coll. **H. of var.** [C21]
fig. 4. " Malvern," [Herefordshire]. ditto **P. of var.** [C22]

Encrinurus onniensis Whittard 1938. Upper Valentian.
Figured Whittard 1938, pl. iv, figs. 8, 9, 10, p. 118.
Onny River Section, near Cheney Longville, Shropshire. ex J. Plant Coll. **S.** [C1]

Heliocephalus coronatus (Thomas 1900), see under *Phacops* (*Dalmania*) *coronatus*.

Homalonotus (*Koenigia*) **knightii** Koenig 1825. Upper Ludlow.
Figured Salter 1865, pl. xii, figs. 7, 8, 8a, p. 119, and by him wrongly referred to sub-genus *Koenigia*, since this species is the genotype of **Homalonotus** Koenig 1825.
" Malvern," [Herefordshire]. Grindrod Coll. [C16]

Illaenus (Bumastus) barriensis (Murchison 1839). Woolhope Shales.
Figured Salter 1867, pl. xxvii, fig. 2 (upper figure), p. 203.
Malvern Tunnel [MS. label gives " Wyche Railway "], Herefordshire. Grindrod Coll. [C13]

Illaenus (Bumastus) barriensis (Murchison 1839). Wenlock Shale.
Figured Salter 1867, pl. xxvii, figs. 3, 5, p. 203.
fig. 3. Malvern Tunnel, Herefordshire. Grindrod Coll. [C14]
fig. 5. ditto ditto [C15]

Illaenus (*Dysplanus*) *bowmanni* Salter 1848. Lower Llandovery.
Figured Salter 1867, pl. xxx, fig. 6, p. 185 ; mentioned as " not *I. bowmanni* " by Reed 1904, p. 59 ; referred to ? **Illaenus thomsoni** Salter 1851, Reed 1935, p. 16.
Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. [C6]

Illaenus (Bumastus) insignis Hall 1864. Wenlock Limestone.
Figures Salter 1867, pl. xxvii, figs. 6a, 6b, p. 207.
Ledbury, Herefordshire. Grindrod Coll. [C12]

Illaenus (Bumastus) maccallumi Salter 1867. Lower Llandovery.
Figured Salter 1867, pl. xxx, figs. 2, 3, p. 210.
fig. 2. Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. S. [C4]
fig. 3. ditto ditto S. [C5]

Illaenus (Dysplanus) nexilis Salter 1867. Lower Llandovery
Figured Salter 1867, pl. xxx, fig. 4, p. 190.
Mulloch or " Drummuck ", near Girvan, Ayrshire. ex Wyville Thomson Coll. S. [C2]

Illaenus (Dysplanus) thomsoni Salter 1851. Llandovery.
Figured Salter 1867, pl. xxx, fig. 8, p. 188. Species identification queried by Reed 1904, p. 70.
Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. [C3]

Phacops caudatus (Brongniart 1822 *non* Brünnich 1781) var. *α*, *vulgaris*. Ludlow.
Figured Salter 1864, pl. iii, fig. 16, p. 51. Following Lindström 1885, p. 37, the species would be named **Dalmanites vulgaris** (Salter 1864) pending further revision of the material.
Ledbury, Herefordshire. ? ex J. W. Salter Coll. [C40]

Phacops **caudatus** (Brongniart 1822 non Brünnich 1781) var. *β*, **tuberculato-caudatus** Murchison. Lower Ludlow.
Figured Salter 1864, pl. iv, fig. 1, p. 53. Species referred to **Dalmanites vulgaris** (Salter 1864), Delo 1935b, p. 425.
Ledbury Tunnel, Herefordshire. Grindrod Coll. [possibly C11]

Phacops constrictus Salter 1864. Wenlock Shale.
Figured Salter 1864, pl. ii, figs. 13, 13a, 14, p. 27. Referred to **Acaste downingiae** (Murchison 1839) var. **constrictus.**
figs. 13, 13a. Malvern Tunnel, Herefordshire. Grindrod Coll. S. [C7]
fig. 14. ditto ditto S. [C8]

Phacops (*Dalmania*) **coronata** Thomas 1900. Wenlock Shale.
Figured Thomas 1900, pl. xxxv, figs. 1, 2, 3, p. 616. Referred to (probably) subgenus *Synphoria* Clarke 1900, Reed 1927, p. 343; to *Malvernia* Delo 1935a, p. 411, as **genoholotype** [1]; subsequently renamed **Heliocephalus** Delo 1936, p. 417, when the name *Malvernia* was found to be preoccupied.
fig. 1. Malvern Tunnel, Herefordshire. Grindrod Coll. S. [C34]
figs. 2, 3. ditto ditto S. [C35]

[1] Delo quotes Thomas' fig. 4 as lectotype of the genotype species. This figure is, however, composite, and either C34 or C35 must be substituted, preferably C35.

Phacops **downingiae** (Murchison 1839) Wenlock Limestone.
var. γ **inflatus.**

Figured Salter 1864, pl. ii, fig. 30, p. 28. The species **downingiae** is genotype of **Acaste** Goldfuss 1843.

Ledbury, Herefordshire. Grindrod Coll. [C9]

Phacops (*Dalmania*) **nobilis** Thomas 1900. Wenlock Shale.

Figured Thomas 1900, pl. xxxiv, figs. 1, 2, p. 617. The name *Dalmania* was considered invalid in trilobite nomenclature by Barrande 1852, R. and E. Richter 1931, p. 141, and Delo 1935b, and is replaced by **Dalmanites** Barrande 1852.

fig. 1. 1 mile east of Builth, 150 yards from bank of Wye, Brecknockshire. Grindrod Coll., ex " Mr. Jones Coll." H. [C24]

fig. 2. ditto ditto H. [C25]

The specimen C25 is the counterpart of C24.

Phacops (*Dalmania*) **nobilis** Thomas 1900. Wenlock Shale.

Figured Thomas 1900, text-fig. on p. 618 ; internal and external casts of eye. Referred to **Dalmanites,** as previous entry.

Same locality as C24, C25. [" Devil's Pitch " on MS. label.] Grindrod Coll. [C27, C26 counterpart]

Sphaerexochus mirus Beyrich 1845. Wenlock Shale.

Figured Salter 1864, pl. vi, fig. 3, p. 76.

Malvern Tunnel, Herefordshire. Grindrod Coll. [C23]

Staurocephalus murchisoni Barrande 1846. Wenlock Shale.

Figured Salter 1865, pl. vii, figs. 15a, 15b, 16, p. 84.

figs. 15a, 15b. " Malvern," [Herefordshire]. Grindrod Coll. [C17]

fig. 16.[1] ditto ditto [C18]

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[1] Figure is an enlargement.

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A Revised Terminology and Subdivision of the Middle Jurassic Rocks of Yorkshire

By J. E. Hemingway

Abstract

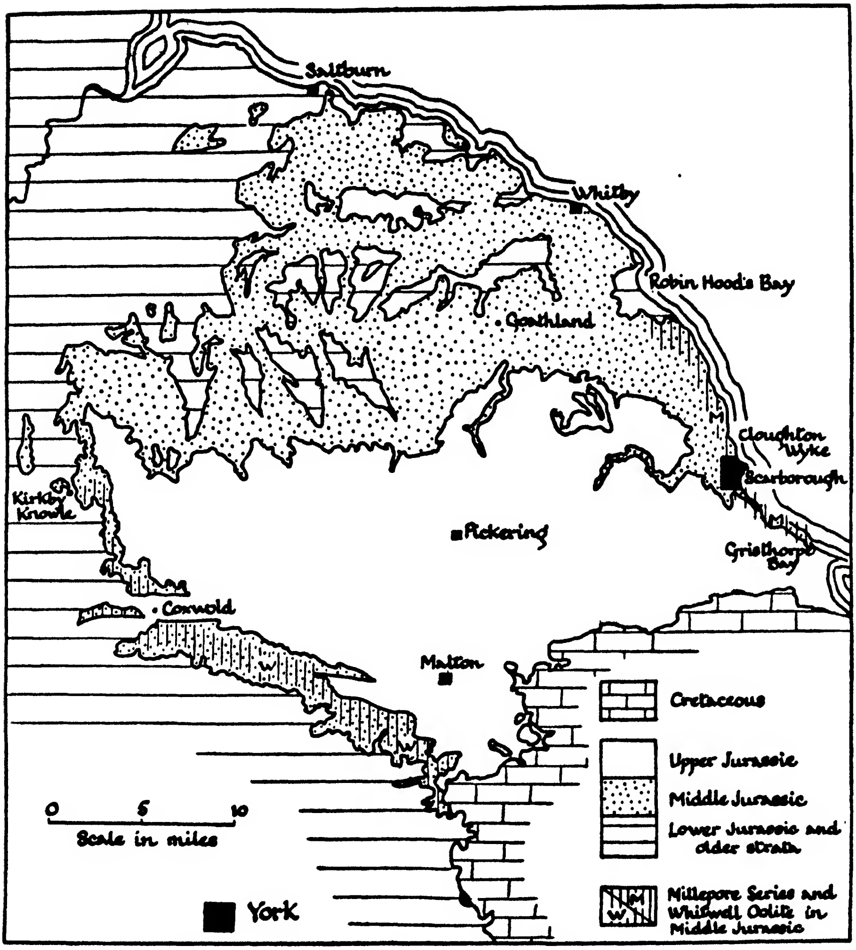
It is suggested (1) that the term "Estuarine Series", as applied to the Middle Jurassic rocks of Yorkshire, should be abandoned and that "Deltaic Series" should be substituted; (2) that the boundary between the lower and middle divisions of this series should be revised and that the persistent Eller Beck Bed should be substituted for that boundary in place of the wedging Millepore Series of the Scarborough district and its inland equivalent, the Whitwell Oolite.

On the occasion of the visit of the International Congress to this country, it is fitting to reconsider the terminology and subdivision of the Middle Jurassic rocks of the Yorkshire basin, with a view to eliminating two inconsistencies.

After being known mainly in terms of their lithology from the time of William Smith, the current nomenclature and subdivision of these rocks was established during the official geological survey of East Yorkshire and adopted by the Survey in 1880 (Fox-Strangways, 1892, table opposite p. 22). It was first published, though not completely, in 1880, in *The Geology of the Oolitic and Cretaceous Rocks South of Scarborough* (first edition), followed in other sheet memoirs of this region and in the better-known compilation from them (Fox-Strangways, 1892). In these publications the Middle Jurassic rocks of Yorkshire were subdivided into Lower, Middle, and Upper Estuarine Series, separated by the Millepore Series (or Whitwell Oolite) and the Grey Limestone Series respectively and underlain by the Dogger (see table, p. 70). This subdivision was adopted in part from the succession established by earlier workers in this province.

The term Estuarine Series is now generally recognized as a misnomer. It was based on Fox-Strangways's interpretation of the conditions of sedimentation in N.E. Yorkshire at this time, which, he maintained, "formed part, either of the estuary of some large river, or possibly of a series of channels or straits between neighbouring islands" (p. 391). It is possible that in this terminology, Fox-Strangways was influenced by Morris's work in Lincolnshire (Morris, 1853). Despite the Survey interpretation, the deltaic character of these beds had been clearly recognized for some time. In 1868 Simpson recorded and appreciated the significance of the several thin but widespread coal seams, the patches of vertical *Equisetum*, and particularly "the shales and deposits of mud [which] have been cut and divided by strong currents of water, and beds of sand [which] have been deposited in the hollows. . . . All these phenomena are in strict accordance with

those presented in the deltas of rivers " (Simpson, 1868). Although Fox-Strangways's unfortunate terminology persisted, the deltaic origin of these beds was favoured (e.g. Kendall and Wroot, 1924). Most recently Black has conclusively demonstrated the deltaic origin of



TEXT-FIG. 1.—Sketch map showing the limited outcrop of the Millepore Series and the Whitwell Oolite in the Middle Jurassic rocks of N.E. Yorkshire and its unsatisfactory character as a dividing bed.

these rocks by tracing the sandstone-filled distributory channels which cut the more regularly bedded sediments and by relating these channels to the locally developed plant-beds (Black, 1928, 1929, 1934*a* and *b*).

In order to obviate the qualification and near-contradiction " so-called ", frequently affixed to the Estuarine Series and also to clarify future reference to the origin of this rock group, the writer urges that the term " Estuarine Series " should be abandoned and " Deltaic

Series " substituted. Attempts to give less committal areal or locality names to the subdivisions, other than the marine beds, have proved unsatisfactory because of the wide distribution of each and the difficulty of defining standard sequences which are both well-exposed and accessible.

A second alteration is also suggested here. The Geological Survey used the marine Millepore Series to separate the Lower from the Middle Estuarine Series. In this Fox-Strangways and his staff, working north-westwards up the Yorkshire coast, adopted for *regional* use a bed which had become well established by earlier and contemporary investigators as a convenient *local* divisional plane, centred mainly on Scarborough. This bed attains a thickness of 40 feet at Yons Nab, four miles S.E. of Scarborough, but it thins to the north-north-west and disappears near Robin Hood's Bay. As an effective boundary therefore it occupies only thirteen miles of coast line. Further, its inland equivalent, the Whitwell Oolite, though more widely distributed, also dies out near Kirkby Knowle, 33 miles north-west of the Market Weighton axis, the southern limit of the Yorkshire Jurassic basin. Thus, over an area of about 340 square miles, which includes by far the greater part of the outcrop of the Middle Jurassics of Yorkshire (400 square miles), the junction between the Lower and Middle " Estuarine " Series cannot be defined, with consequent confusion in terminology (Text-fig. 1). It is therefore suggested that this boundary should be revised, by using the Eller Beck Bed in preference to the Millepore Series.

The marine Eller Beck Bed, which occurs from 100 feet to 170 feet above the Dogger, was first recorded near Goathland during the official survey (Barrow, 1877) and was included in the Lower Estuarine Series. It outcrops in N.E. Yorkshire from near Cloughton to Brotton and Boosbeck near Saltburn and southwards down the western escarpment to Coxwold. Here it passes from a ferruginous to a calcareous facies, the Hydraulic Limestone, which continues south-eastwards to the Humber. It may also be traced round the several Cleveland inliers as a readily mapped horizon, and has been found by the writer to be more widely distributed than the Survey 1 in. maps indicate. It is undoubtedly persistent throughout the whole outcrop of the Middle Jurassic of Yorkshire.

On the grounds of convenience alone the claims of the Eller Beck Bed as a boundary between two parts of the Deltaic Series are clearly superior to those of the impersistent Millepore Series. Further, Professor T. M. Harris informs me and kindly allows me to state that in an examination of the plant spores in the fine-grained sediments of the Yorkshire Deltaic Series, marked breaks in the distribution of the several types occur at the Eller Beck Bed and the Grey Limestone

Series, but not at the Millepore Series. The case for revised subdivision therefore appears to be established. It is suggested that the Eller Beck Bed should be used to separate a reduced Lower Deltaic Series from an expanded Middle Deltaic Series: the wedging Millepore Series should be relegated to a less important role in the Middle Deltaic Series: and for convenience of reference, in localities where the Millepore Series is developed, the lower part of the Middle Deltaic Series may be termed the Sycarham Sub-Series and the upper part the Gristhorpe Sub-Series, each from localities near which the relevant beds are well exposed.

The changes may be summarized as follows, with revised maximum thicknesses from unpublished work by Dr. M. Black and the writer :—

Fox-Strangways's Terminology	Revised Terminology	
Upper Estuarine Series, *c.* 200 ft.	Upper Deltaic Series, *c.* 200 ft.	
Grey Limestone Series, 27 ft. to 104 ft.	Grey Limestone Series, 27 ft. to 104 ft.	
Middle Estuarine Series, 100 ft. to an undefinable thickness.	Gristhorpe Sub-Series	
Millepore Series, 40–0 ft.	Millepore Series, 40–0 ft.	Middle Deltaic Series, 250 ft.
Upper part of Lower Estuarine Series, 150 ft. to an undefinable thickness.	Sycarham Sub-Series	
Eller Beck Bed, 4 ft. to 17 ft.	Eller Beck Bed, 4 ft. to 17 ft.	
Lower part of Lower Estuarine Series, 100 ft. to 170 ft.	Lower Deltaic Series, 100 ft. to 170 ft.	
Dogger 0 ft. to 40 ft.	Dogger 0 ft. to 40 ft.	

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CORRESPONDENCE

INDEX FORAMINIFERA OF THE CHALK

SIR,—Considerable research has been undertaken during the last few years, particularly by petroleum geologists, to establish zonal indices among the foraminifera of the Chalk of England, Sweden, and North Germany. The English Chalk has been studied by E. Williams-Mitchell and the Swedish by Dr. F. Brotzen, while at least six workers, Altaner, Bettenstaedt, Hiltermann, Olbertz, Wedekind, and Wicher, have made valuable contributions towards this subject in North Germany. The results of all these studies are now available in published form.

The Anglo-Iranian Oil Company, London, have received from Dr. O. Heermann, of the Deutsche Vacuum Oil Company, the gift of a topotype set of some of the material from borings at Cuxhaven and Siegfried, consisting of named and mounted index species of each zone from the Turonian to the Maestrichtian.

In order that this material may be available to students the Company have decided to present it to the British Museum (Natural History), where Mr. C. D. Ovey is gradually building up a collection of Mesozoic and Tertiary material, his ideal being to accumulate as complete a stratigraphical sequence as possible, solely for the purpose of studying the microfauna zonally and biologically. Both from this aspect and from the fact that many important type collections, including F. Chapman's and Williams-Mitchell's Chalk specimens are preserved there, the Cuxhaven and Siegfried material is obviously an enhancement.

A. G. DAVIS.

ANGLO-IRANIAN OIL COMPANY.
10th November, 1948.

THE TERM "MAGMA-TYPE"

SIR,—In their recent paper "On Magma-Types and their Nomenclature" (*Geol. Mag.*, 1948, p. 349) Mr. M. K. and Dr. A. K. Wells seem to be straining at a couple of inoffensive gnats whilst swallowing with relish a particularly monstrous camel. I am grateful to my two friends for providing me with a suitable opportunity for making a protest—long overdue—against the use and misuse of the term "magma-type". Far too many petrologists have fallen into the habit of speaking of "magma-types", or even of "magmas", when they simply mean rocks. Scientific jargon, appropriate to the circles in which it is understood, cannot be altogether avoided, but this particular example is so definitely unscientific and mischievous that it has become a positive danger.

Defined objectively, a so-called "magma-type" is the mean of a number of chemical analyses of rocks (of igneous or supposedly igneous origin) so similar in composition that the deviation of each constituent from its mean

value is small. By a natural extension of associative meaning the term is commonly applied to any member of a class of rocks so characterized. The term itself, however, is a complete misnomer, because it inevitably carries with it the implication (*a*) that the rocks concerned have crystallized either from a common magma or from magmas of closely similar composition, and (*b*) that the composition of the parental magma or magmas corresponds approximately to that of the rocks from which the type is abstracted. How serious the resulting confusion of thought can become is illustrated on p. 349 of the paper under consideration, where the authors state that a " magma-type " " was meant to be only a little different from a ' rock magma ' ".

The real conception behind the term is one of similar composition and, in itself, it has not necessarily anything to do with magmas. In a word, a " magma-type " is not a type of magma ; it is a statistical concept. But composition alone rarely serves to discriminate between different modes of origin. Yet the term implies by its verbal tyranny that the mode of origin of the class of rocks concerned is already known, and that it is indisputably magmatic. Recognition of the real problems of petrogenesis thus tends to be inhibited by the hypnotic spell of an unduly generalized hypothesis for which genuine supporting evidence can be found in only a few rather obvious cases. The authors of the Mull Memoir were admittedly dealing for the most part with one of these more obvious cases, but this excuse cannot be made for others—I am thinking especially of Niggli and Billings—who have made the term a real menace to understanding and progress by extravagantly applying it to hosts of classes of rocks for which a magmatic origin has never been demonstrated.

Another example of a term which embodies a hypothesis as if it were an established fact is " Comagmatic ". Judd's " Petrographic Province " is a straightforward descriptive term that raises a most intriguing problem without presuming to prejudge the issue. Washington's " Comagmatic Region " hides the problem by implying a hypothetical solution in advance. The potash-rich volcanic rocks adjoining Ruwenzori in S.W. Uganda constitute a highly individualized petrographic province, but I have so far been unable to demonstrate that they are " comagmatic ". I mention this case because I cannot agree that the rocks concerned illustrate what Wells and Wells (p. 350) call a good example of a " magma-type ". The remarkable geochemical peculiarities of the rocks point to a high degree of consanguinity,[1] but their complex heredity has been so much modified by the effects of environment that no satisfactory genealogy can, as yet, be disentangled.

Petrological terms, both in form and definition, should as far as possible be purely descriptive and free from hypothetical petrogenetic implications. I feel very strongly that of all the many terms that fail in this respect " magma-type " and " comagmatic " are amongst the most unwarranted and the most dangerously misleading. In place of " magma-type " an objective term such as " composition-type " would adequately convey all that is needed.

As to the " gnats " of my opening sentence, I have not found in practice that the terms " olivine-basalt " and " tholeiitic " give rise to any ambiguities when used in their proper context. The proposed alternatives, however, fail to suggest—to me, at any rate—the right associations. " Simatic " suggests rocks of unknown, but probably ultrabasic composition, and is therefore too broad and ambiguous for a " type " name. " Sub-sialic " embodies a hypothesis ; " sub," moreover, suggests olivine to followers of Shand's nomenclature, whilst " sialic " distracts attention from the idea of basaltic composition ; the term is therefore inappropriate.

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15th December, 1948.

[1] It should be pointed out that this term was not coined by Harker, as stated on p. 355, but was first adopted in a petrogenetic sense by Iddings (see Harker's *Natural History of Igneous Rocks*, p. 89).

ON THE SO-CALLED METAMORPHISM OF THE TRIAS IN THE ALPS

SIR,—Many readers must have welcomed O. T. Jones's article under the above title in the *Geological Magazine*, 1948, p. 333. It recalls metasomatic effects of weathering which concern us all, whether our interest be general or particular, in which latter case it may be focused on such matters as soil or laterite, including bauxite, or the leaching and secondary enrichment of metalliferous ores. I could not help being reminded of my own "Subterranean Penetration of a Desert Climate", published in your pages in 1926; and even more of J. E. Richey's account in the Geological Survey Memoir on Ardnamurchan (1930, p. 35) of phenomena associated with Triassic cornstones: "These chemically-formed limestones, deposited from solution, are at some localities found at the base of the Trias, and in this position they are seen to have permeated and partly replaced the underlying quartzose and felspathic schistose rocks in an intricate manner. The lime-bearing solutions have attacked the schists more especially along their bedding-planes, so that cornstone is found interleaving with these much more ancient rocks." Richey then points out that other Triassic examples of the same phenomenon had been described by myself in 1925 from Inch Kenneth, off Mull, and by Albert Heim in 1920, from an Alpine locality—he might also have added by Clough in 1910 from Skye, in the Geological Survey Memoir on Glenelg, p. 91. A more recently discovered locality has been described by me from Rhum, in a *Quarterly Journal* paper, 1945 (for 1944), p. 175. Partial replacement of schist by limestone at the base of a cornstone (here of Upper Old Red Sandstone or Lower Carboniferous date) is also capitally exposed at Loch Ranza in Arran. The locality is famous because it furnished James Hutton in 1785 with an example of angular unconformity. Hutton's description in his third volume of *The Theory of the Earth*, not published till 1899, is very restrained in regard to the metasomatic phenomena. The rocks above and below the unconformity are, he says, "somewhat confused at the immediate junction."

E. B. BAILEY.

19 GREENHILL GARDENS,
EDINBURGH.
18th December, 1948.

STUDIES IN THE MONA COMPLEX—THE BASE OF THE BEDDED SUCCESSION

SIR,—In the *Anglesey Memoir* (p. 168), an opinion was expressed, which was proven decisively in 1923 [1]; that between the Bedded Succession and the Gneisses there must be an unconformity, and of the first magnitude. Yet, on p. 169, I add "but this unconformity has never been found, and within the limits of Anglesey, has probably been cut out everywhere by thrusting". Is that, however, probable? In our chapter on the Succession we traced a number of horizons which, if cut out locally, did escape at other places. Why should this one never escape? How did I come by such an opinion? I think it was that really I was expecting a basal conglomerate, with boulders of the gneisses, and never finding such a bed, supposed that I had not reached the base. There was a still stronger reason. When I wrote that sentence, although (see table on p. 164, *Anglesey Memoir*) I had come to realize that the Fydlyn Beds were the lowest *known* member of the Bedded Succession, they had not been recognized to the north of the Carmel Head thrust plane. Not long afterwards they were, as shown in my paper of 1923. And the matter

[1] *Quart. Journ. Geol. Soc.*, lxxix, 334–351.

of importance is that at Mynachdy they are adjacent to gneisses, with no room for anything between. The natural inference would have been that this is their true stratigraphical base and that they rest upon the Gneisses.

Still, there is no conglomerate. Why? Because the Fydlyn Beds are volcanic, mainly rhyolitic dust, and the base of such an accumulation must differ in important respects from a sedimentary base. Deposition, in such a case, was not preceded by erosion. And without erosion there would be no conglomerate.

From its uniformity and its very wide extension, this dust probably was showered not from a few major cones, but from a crowd of little vents, like the Mexican "hornitos" of two centuries ago. Which leads us to a further point. For the hornitos were upon land and the Fydlyn Beds, unlike so many of our old volcanic rocks, unlike their successors the Gwna spilites, do not appear to have been marine.[1] Further still, the Gneisses, under long continued terrestrial conditions, would be deeply decomposed, as are the granites of southern Cornwall. When the hornitic explosions began, this friable product of decay would not break up into blocks: it would disintegrate throughout, and blow abroad into the air, would mingle intimately with the rhyolitic dust. Thus two formations, parted really by a long interval of time, would seem to graduate into each other, so that a very great unconformity would be effectively concealed.

Connected with this is another feature: their thickness is most variable and on an enormous scale. In the Aethwy Region, where they are in the condition of mica-schist, they must be 3,000–4,000 feet, whereas at Mynachdy they can be hardly as much as 100 feet. If they were showered upon mountainous land this becomes intelligible: they could thin away rapidly from several thousand feet to nothing. Now we do know of a land, also sculptured out of gneisses, and apparently of like antiquity, which is visibly mountainous . . . the famous land of the Lewisian. We seem, in the present case, not by sight but by indirect evidence, to obtain a glimpse, if dimly, of a somewhat similar land beneath the base of the Bedded Succession.

EDWARD GREENLY.

AETHWY RIDGE,
BANGOR.
August, 1948.

REVIEWS

ERUPTIVE ROCKS. By S. JAMES SHAND. Third edition, 1947. Thomas Murby and Co., 40 Museum Street, W.C. 1. xvi + 488, 51 figs. and 4 Plates; 30*s*.

The third edition of this well-known and stimulating work is a great improvement on its two predecessors. The previous material has been brought up to date and three new chapters on late-magmatic and post-magmatic reactions, the genesis of pegmatite, and eruptive rocks and ore deposits have been added. Moreover, the book has now been divided into two, with the rock descriptions forming a separate Part II. This is a textbook which should be in the hands of every advanced student of petrology.

[1] On Fydlyn beach there are some strips of grey phyllite which have a sedimentary aspect. But they are of trifling thickness, a few inches at the most. May we venture a suggestion that they were deposited in pools, like those of St. Vincent, in 1902, described by Anderson and Flett?

THE STUDY OF ROCKS. By S. J. SHAND. Second edition, 1947. Thomas Murby and Co., London. xi + 236 ; 10*s.* 6*d.*

A revised and enlarged edition of this useful little introduction to the study of rocks. It is a pity that room could not be found for at least a few text-figures or plates to illustrate some of the rock types described.

S. R. N.

GEOLOGY OF THE COUNTRY AROUND WEYMOUTH, SWANAGE, CORFE, AND LULWORTH. By W. J. ARKELL. Memoirs of the Geological Survey of Great Britain, 1947. Price 17*s.* 6*d.*

It is nearly a century since the publication of the first Survey map of this area, already classical from the work of Fitton, Clarke, Fisher, and others ; it is half a century since Strahan's revised mapping and the publication of his Purbeck and Weymouth Memoir. Both fifty-year intervals were marked by great advances in geological ideas, particularly in tectonics. Strahan was necessarily influenced by Lapworth's recent classical work in the Highlands and its development by Peach and Horne, and Professor Judd's comment made to this reviewer was : "Every strike-fault is called a thrust nowadays." The last fifty years has been marked by great progress in zonal stratigraphy and refinement in palaeontology, as well as by further advances in tectonics, while many new facts have been found by deep borings in the district. At the same time some old controversies have been practically forgotten, such as the question whether the Purbeck beds were Jurassic or Cretaceous, to which Strahan devoted five pages ; while Judd's blunder over the tumbled sequence at Punfield now needs only very brief mention.

All the stratigraphical chapters in this new memoir show the care and thoroughness that we expect from Dr. Arkell, though the only really big novelty, as compared with Strahan, is the recognition of the Bembridge Limestone fauna on Creechbarrow.

A point of special interest to the reviewer is the inference from the *Cassiope* fauna of Punfield that "a direct marine connection with Spain, down the Channel, is indicated" (p. 169). This agrees with the restriction to Wiltshire, in the Aptian, of the Tethyan genus *Toucasia*, and to Devonshire, in the Albian, of *Orbitolina*.

The tectonic chapter is of great interest, in view of the complexity of structure. particularly along the base of the Chalk scarp. The Oxford Clay "dyke" in the Upwey railway-cutting, and the Cornbrash of Bincombe village are century-old puzzles, to which must now be added the Forest Marble in the brook near Sutton Poyntz waterworks (discovered by a Royal School of Mines mapping class twenty years ago, but never followed up until rediscovered by Dr. Arkell), and the Oxford Clay and Cornbrash at the foot of White Horse Hill, found during Kent's oil-prospecting. These four areas alternate with others in which Portland and Purbeck come immediately under the Upper Cretaceous, while borings at Sutton Poyntz (pp. 266–271) show these two types of sequence superposed. Dr. Arkell's explanation of these anomalies is based on the interaction of intra-Cretaceous and Tertiary earth-movements, each followed by great denudation, the earlier being post-Wealden, pre-mid-Albian.

Pleistocene history and the development of topography occupy twice the space given to them in Strahan's memoir.

The improvement in the illustrations and general get-up, as compared with the old memoir, is revolutionary. The Survey and Dr. Arkell are both to be congratulated on a very fine production, regrettably delayed for eight years by the war.

A. M. D.

SYMPOSIUM OF INFORMATION RELATIVE TO USES OF AERIAL PHOTOGRAPHS BY GEOLOGISTS. Compiled by Professor H. T. U. SMITH. *Photogrammetric Engineering*, vol. xiii, pp. 531–628, 1947.

Air photography is now well established as a valuable instrument of research in geology and geography. To the cartographer it is an indispensable aid to the mapping of unknown or ill-explored areas, particularly if they be desert or difficult of access, while to the geologist it is of special interest not only in recording surface features like rivers and rock-formations, but also, when conditions are suitable, in revealing underground structure. The wide range of interests involved is apparent from the diversity of papers offered at this symposium. Several authors write about the use of air photographs, both vertical and oblique views, for geological mapping. Two text-figures illustrating the geology of an area under forest, as determined by ground survey and as interpreted from air photographs, make an interesting comparison. The correspondence is remarkable, but without the actual photographs in question it is impossible to judge the skill needed for interpretation ; so much detail is lost in reproducing air photographs as half-tones. The extent to which solid geology may be disclosed by air photography depends very largely on the nature of the earth's surface, and the occurrence of masking soil and vegetation. When contrasted rock types are present, dense vegetation may disclose outcrops by differential growth. In Britain the structural uses described in these papers are hardly possible, and the real value of the air photograph is as a base for field-mapping.

An account of the mapping of an area in Alaska from photographs taken by the trimetrogon process shows how under suitable conditions reconnaissance geological maps can be made of quite extensive districts with a minimum of flying. These papers, however, emphasize very rightly the need for familiarity with the ground, and for photographic evidence to be checked in the field if reliable maps are to be made. Air photography can disclose geological structures in comprehensive view, and can guide us to a particular feature, but the next stage in mapping will always be with the ground surveyor who can make much more detailed observations than the airman.

Other papers deal with the use of air photographs in recording and disclosing surface features, whether varieties of soils or aspects of physical geology. This is a field in which oblique photographs are specially valuable. Many landscape features can readily be recorded in air photographs in comprehensive views that can never be obtained at close quarters. Coastal topography, river-systems, and glacial features are particularly susceptible to this treatment, and a collection of such views would be of great value to geomorphologists. The importance of these photographs for teaching is recognized in other sections of the symposium, and some of the remarkable photographs of physical features which are reproduced speak for themselves.

J. K. ST. J.

GEOLOGICAL EXPLORATIONS IN THE ISLAND OF CELEBES. By H. A. BROUWER, W. P. DE ROEVER, and C. G. EGELER. pp. 346, with figures, 18 plates, and maps. Amsterdam : North Holland Publishing Company, 1947. Price f. 27·50.

This volume sets forth the results of a geological exploration in Celebes under the leadership of Dr. H. A. Brouwer. It consists of three separate memoirs : a summary of the results by the leader, 64 pages, and two long descriptions of the metamorphic rocks of different areas by Messrs. W. P. de Roever and C. G. Egeler respectively.

Celebes is surely the queerest shaped large island in the world : and it is a large island, nearly 700 miles from south-west to north-east. It was at one time thought that its structure differed considerably from that of the Malayan region generally, but this seems not to be so. In any case, however, the run of the fold lines in this region must be very complicated, as shown by a general map, which differs much from the apparent simplicity of the

outer Sumatra–Java–Timor arc. And the neighbouring island of Halmahera is very like Celebes on a smaller scale. The shape of the island makes it very difficult to discuss its geology without a map; since, for example, the "northern" peninsula runs due east and west for over 200 miles. This book deals mainly with the central area where the four peninsulas run together in a sort of wasp-waist only about 50 miles across from north to south. Across this waist runs an important structure, a crush-zone, here called the Median Line, and there are important differences in the geology on either side of this line. On the west plutonics of a granodiorite facies and acid volcanics are abundant, while on the east the intrusions are mostly ultrabasic and basic, and metamorphic rocks are not very common. To the west, however, metamorphism is strongly developed, especially in a facies characterized by glaucophane. The age of the metamorphic series is unknown, and there is no positive evidence for the existence of Precambrian or Lower Palaeozoic rocks. Certain Palaeozoic fossils formerly recorded are now believed to have come from a Chinese chemist's shop.

The oldest rocks to which an age can be more or less definitely assigned are certain bituminous limestones and shales with *Productus* and so on, which may be Permo-carboniferous. To the reviewer this suggests a possible relation to the black-banded limestones and black shales of the Raub System of the Malay Peninsula. The presence of Trias is well-established and Dr. Brouwer thinks the Jurassic-Cretaceous sequence may be complete. There is evidence of much disturbance in the Tertiary and the granodioritic facies in both its intrusive and eruptive phases is Tertiary, and this is continued up to the present by more or less active volcanoes, mostly dacitic. In some places reef-limestones have been elevated as much as 2,000 metres.

The structure of the island is obviously very complicated, though not much is definitely known about it, no doubt owing to the usual difficulties of field work in a humid tropical climate. There are probably recumbent folds (nappes) and klippen, with much faulting and some obvious rift valleys. The theories for the origin of these last are discussed. Among other puzzling features it is found that some lake-basins descend well below sea-level, in spite of the raised reefs.

The two petrological memoirs consist of elaborate descriptions of the two facies of metamorphic rocks, one of which contains several peculiar minerals. For purely geological reasons it is believed that the two facies are of different ages, though what these ages may be there is as yet nothing to show. It is clear that there is still much of interest to be discovered in the geology of Celebes. It is important to realize that in the Dutch East Indies there is evidence of acid plutonic intrusions in the late Tertiary, probably as late as the Pliocene. R. H. R.

THE GEOLOGY OF UBEKENDT EJLAND, WEST GREENLAND, PART I. By H. J. DREVER and P. M. GAME. pp. 34, with 8 plates and 10 figs. Meddelelser om Grønland. Vol. 134, No. 8. Copenhagen, 1948. Price Kr. 2.50.

This is a preliminary account of the results of two expeditions to West Greenland from Cambridge and St. Andrews in 1938 and 1939. The island, which lies opposite to Upernivik, is about 20 miles by 14, and consists of a great variety of igneous rocks. The earliest phase was mainly picritic flood basalts, of enormous but unknown thickness, the base not being seen. They dip generally S.W. at 20°–25°. This was followed by a period of central eruption, including olivine-free basalt, rhyolite, and trachyte, followed finally by an explosive phase. There are also gabbro, granite, microgranite, and felsite, as well as breccias, tuffs, and dykes, often acid-basic composites. The early eruptions seem to have been of fissure type as indicated by tholeiite dykes. The whole thing shows a certain affinity to the Isle of Mull, but it is obvious that much more work, which will be awaited with interest, will be required in the island and on the abundant material brought home by the expeditions. R. H. R.

MALAYAN UNION. REPORT OF THE GEOLOGICAL SURVEY DEPARTMENT FOR THE YEAR 1947. By H. SERVICE. pp. 39, with 2 maps, one coloured. Kuala Lumpur: Government Press, 1948. Price 3*s.* 6*d.*

In the absence of the Director on home leave, this annual Report is written by the Acting Director. It records a general progress of recovery from the devastation caused by the Japanese invasion: in particular the chemical laboratory seems to have been more or less restored to normal conditions. Mineral production in the country during 1947 was increased though new ventures are still considerably handicapped by a general loss of prospecting records. Much attention has also been paid to the possible development of hydro-electric plants. But to geologists in general the most interesting feature of the Report is the record of a large fauna from near Kuantan in Pahang. The fossils have been named and described at the British Museum (Natural History), and are found to be of Viséan age. They include some trilobites, assigned to *Phillipsia*, the first fossils of this kind to be found in the country. The rest are mostly brachiopods, with a few mollusca and corals.

R. H. R.

EMANUEL KAYSER'S ABRISS DER GEOLOGIE. Zweiter Bd., Historische Geologie. 6th edition, completely revised by R. BRINKMANN. pp. vii + 355, with 64 figures and 58 text-plates. Stuttgart: Ferdinand Enke, 1948. Price 25 Marks (geb., 27 Mk.)

This must be one of the first geological textbooks to come out of post-war Germany; the paper is rather poor, as usual throughout Europe to-day, but the typography and general style seem well up to pre-war standard of the Stuttgart and Berlin publishers, and the book has much to commend it for any student to whom the German language presents no difficulties.

The standard seems to be about that of our Pass Degree, but the field covered is considerably larger than that of the ordinary pass degree of this country since the survey is world-wide; moreover, it is remarkably well balanced, though the emphasis is naturally upon Europe and upon Germany in particular. Details of stratigraphical successions are left entirely to correlation tables, and find no place in the text, which is accordingly far more readable than the majority of stratigraphical textbooks. The plan adopted for each system is a brief introduction and definition, followed by a general account of the principal areas of development (often illustrated by palaeogeographic maps); then comes a fairly full discussion of the fauna and flora, well illustrated in a manner reminiscent of the "Stanford Atlas" plates, though fuller and much more up-to-date. Whilst the Cambrian has 12 figures on one "text-plate", the Cretaceous has 82 figures on 11 plates. The account of each system concludes with a general discussion of climate, palaeogeography, crustal movement, etc., and is illustrated by a world palaeogeographic map. One cause for regret is that, while a vast amount of literature has obviously been drawn upon in the compilation of this work, the references cited at the end of each chapter are extraordinarily few and those few most curiously chosen.

O. M. B. B.

STRUCTURAL GEOLOGY OF CANADIAN ORE DEPOSITS—A SYMPOSIUM. 8vo. pp. x + 948. Canadian Institute of Mining and Metallurgy, 1948. Price $10.00.

This splendid volume, which fittingly commemorates the fiftieth anniversary of the founding of the Canadian Institute of Mining and Metallurgy, assembles a wealth of information concerning structural features that have influenced

the localization and form of ore-bodies in Canadian metalliferous areas. Whilst the nature of the ore fluid, its composition, and mode of transportation are all problems of intriguing interest, of greater significance in the actual search for ore are the recognition of mineralogical and lithological guides, and especially of structural controls that so largely determine the locus of ore deposition. Fissures, joints, faults, shears, brecciation zones, and kindred fractures not only afford requisite channel-ways for the entry of metallizing solutions, but also serve as sites for the precipitation of ore minerals and as the starting-places for the progressive evolution of replacement ore-bodies. Within recent years growing emphasis has been laid on the role of geological structure in the emplacement of epigenetic mineral deposits, and it becomes increasingly clear that a proper appreciation of the relevant structural factors in a mineralized district can aid considerably in planning the further development of operating mines and in the exploration for virgin ore-bodies.

An avowed object of this volume is a " stock-taking " of existing information correlating structure and ore deposition within a wide range of individual mines and districts throughout Canada. It is a stimulating collection of papers, replete with local detail and structural analyses, which merits the careful study of all geologists and mining engineers interested in the discovery and development of metalliferous deposits.

The Symposium gathers together in 132 separate papers the work of more than 120 contributors, and is copiously illustrated with admirably neat line drawings and many half-tones of photographs. Most of the papers on individual mines have been written by the mine geologists themselves, the general papers describing more extensive tracts being contributed mainly by government geologists. The volume opens with valuable synoptic papers by Lang, Gill, and Alcock, summarizing the general geology, mineralization, and structural controls within the three most productive provinces of Canada, namely the Cordilleran, Canadian Shield, and Appalachian regions. These are followed by descriptions of the principal structural controls within particular mining fields, such as those of Yellowknife-Great Bear Lake, Porcupine, Sudbury, and Nova Scotia, supplemented by a long series of articles on structures related to mineralization at individual mines. In many cases the disposition of lodes and vein-patterns agrees closely with the theoretical directions of shear and tension fracturing indicated by appropriately oriented conventional strain ellipsoids. At numerous mines a clear distinction is recognized between favourable and unfavourable rocks, and commonly an intimate relationship can be discerned between mineralization and rock competence, fracture deflections, folding, and structural barriers that have impeded the flow of metallizing fluids.

Readers in Britain will probably find most interest in the regional papers and in the up-to-date views on such famous mining camps as Sullivan, B.C. (lead-zinc), Eldorado (uranium), Porcupine and Kirkland Lake (gold), and Sudbury (nickel-copper-platinum). Yates, in a masterly description of the Sudbury district, indicates how untenable is the classical hypothesis of Coleman and others which attributed the localization of the nickel sulphide deposits at the base of a norite sill to a process of gravitational segregation *in situ*, and himself emphasizes the role of later intrusions of quartz diorite and breccias in controlling the locus of ore deposition. It is interesting to note that whilst Yates asserts that the position and shape of the norite was governed by its intrusion into a large, pre-existing syncline, Cooke concludes that the norite must have been injected, and consolidated, before the Sudbury basin began to develop. In the Porcupine district the locus of gold-ore deposition was chiefly determined by the degree of deformation, especially of shearing, that was produced by folding. Here, as in so many other areas, structure and variations in rock competence seem to have been of greater significance in controlling the sites and form of ore-bodies than any possible genetic relationship between mineralization and near-by igneous intrusions. The importance of neighbouring intrusive stocks and dykes lay largely in their influence on the distribution of later fracture zones which

facilitated the entry of ore-bearing solutions, and often there is no direct consanguinity between the ore-bodies and accompanying intrusive rocks.

This outstanding book, summarizing the views of Canadian geologists on the structural control of ore deposition, will be a welcome guide and stimulus to all engaged in the search for ore, and is confidently recommended to everyone interested in the problems of ore localization. Thanks are due to the Symposium Committee, under the Chairmanship of M. E. Wilson, for assembling a feast of detailed and general information in such an attractive and worth-while volume.

D W.

THE COAST OF NORTHEAST GREENLAND. By LOUISE A. BOYD. x + 339, with 194 figures and separate case with 12 folding maps and panoramas; American Geographical Society, special publication No. 30. 1948.

Here are the collected results of expeditions to N.E. Greenland in 1937 and 1938, publication of which was suspended during the war for security reasons. A Norwegian vessel, *Veslekari*, was chartered, and the trips included visits to West Spitsbergen and Jan Mayen. Miss Boyd, in addition to financing and leading the expeditions, used a variety of equipment to obtain a large number of excellent photographs. Apart from providing a pictorial record of much of the coastline visited, some photographs have been used subsequently for the construction of maps by employing simple techniques described by F. W. Buhler and J. M. LeRoy. One may well wonder whether the energy of the six porters (p. 87) could not have been better employed in establishing phototheodolite stations.

The main work of the expeditions was hydrographical. LeRoy describes the echo sounding equipment used both on the *Veslekari* and on a motor-boat. The results are shown on a series of charts. One new feature discovered was Louise A. Boyd Bank, approximately 73° N., 3° E., where there is a rise from an average depth of 2,500 to 600 metres.

R. F. Flint and A. L. Washburn were the geologists on the 1937 expedition and describe in detail many glacial features of the regions, but any general conclusions must await more detailed work. In 1938 a much smaller geological programme was possible. One interesting feature was the description by F. E. Bronner of an apparently post-glacial laterite (p. 223) derived from metamorphosed basic intrusions and sediments on a newly described island 76° 41′ N., 19° 55′ W., on the Orientering group. Botanical collections and current, tide, and magnetic observations were also made. The fine quality of the publication has certainly displayed the expeditions' achievements to the best advantage.

' B H.

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An Alkali Facies of Granite at Granite-Dolomite Contacts in Skye

By C. E. Tilley

(PLATE I)

Abstract

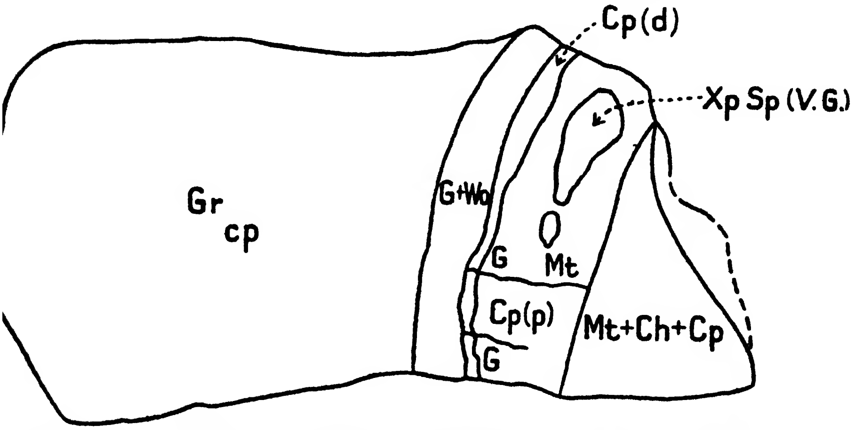
The development of an alkali pyroxene-bearing facies of granite at the contact of the Beinn an Dubhaich granite of Skye with Durness dolomites is associated with a skarn formation involving magmatic transfer of alumina. The significance of the processes at work in this and related examples is discussed.

THE investigation of the skarns associated with the contact of the Durness dolomites and the Tertiary Beinn an Dubhaich granite of Skye has afforded, in a region of detailed survey mapping, an opportunity for the study of endomorphic processes at granite-dolomite contacts, on which subject in Skye, data have hitherto been lacking. In a note on the mineralogy of these skarns (Tilley, 1948), reference was made to the occurrence of localized marginal facies of the granite, linked with the skarns. It is one of these examples I propose to discuss in the present contribution.

As detailed by Harker (1904) in the Skye memoir the Beinn an Dubhaich granite mass is a uniform medium-grained hornblende-biotite type with granitoid texture, resembling in its mineralogy some companion granites of the Red Hills. At the dolomite contact skarns the hornblende and biotite give place to clinopyroxene and the texture of the granite may be considerably affected, becoming not infrequently finer-grained. The petrographical character of these marginal facies of the granite is found to stand closely related to the nature of the exomorphic skarns with which they are intimately associated.

The particularly marginal facies of granite now under discussion is characteristically associated with a group of zoned skarns which have as inner members against the granite a grossularite-wollastonite assemblage. Such examples are particularly to be found at No. 1 Prospect, Kilchrist, at Kilbride, and best of all, at a locality on the southern border of the granite, 1 mile E.S.E. of Camas Malag. The characteristic feature of this alkali granite type of endomorph is the association of a deeply coloured clinopyroxene with quartz and a microperthitic felspar. This facies is normally limited to a few inches from the skarn contact, but at the last locality referred to above, the

zone reaches a foot or more in width. At this locality the alkali granite forms a lens in the marble close to the main granite contact: as exposed this is about 15 feet long, with a width of not less than 4 feet, but the whole contact with the marble is not seen. Specimens collected from the lens appear to be wholly of alkali type. The rock is a grey-white granite spotted with black pyroxene, often fine-grained but sometimes with larger microperthites showing typical micrographic texture



TEXT-FIG. 1.—Diagrammatic sketch and explanation of Fig. 1, Plate I. Gr_{cp} (clinopyroxene granite), G grossularite, Wo wollastonite, Cp (p) pale clinopyroxene, Cp(d) dark clinopyroxene, Xp xanthophyllite, Sp spinel, V vesuvianite, Mt magnetite, Ch chondrodite.

EXPLANATION OF PLATE I

FIG. 1.—Marginal facies of granite associated with zoned skarn, No. 1 Prospect, Kilchrist (× $\frac{7}{8}$).
The granite at the marble contact bears green soda clinopyroxene and shows larger microperthites with micrographic texture: immediately bordering it is a zone of grossularite-wollastonite. This is followed by a thin zone of dark clinopyroxene (Cp(d)), a coarse pale clinopyroxene zone (Cp(p)) with dark patches rich in spinel, vesuvianite, grossularite, and xanthophyllite, and finally the ore zone built of magnetite, clinopyroxene, and chondrodite. Analysis of the grossularite–wollastonite zone of this specimen is given in Table 5, No. 1.

FIG. 2.—Biotite-hornblende granite of the Beinn an Dubhaich mass, N. of Camas Malag, Loch Slapin (× $\frac{3}{4}$).
Typical granitoid texture with white idiomorphic oligoclase. (For comparison with Fig. 1).

(cf. Plate I, fig. 1, from a Kilchrist example). Independent albite crystals are rare, usually this mineral appearing in streaky perthitic intergrowth, sometimes in broader plates continuous with orthoclase or as narrow fringes thereto. Accessory minerals include sporadic sphene.

1

2

GRANITE-DOLOMITE CONTACTS IN SKYE.

The clinopyroxene varies considerably in colour in different examples; usually it is a pale green type, lighter at the core and often strongly zoned. At Kilchrist, where zoning is less pronounced, the pleochroism is a = light green, γ = yellow to brown green and $\gamma \wedge c = 53°$. These features correspond to a diopside-hedenbergite with small amounts of aegirine in solid solution. At the locality E.S.E. of Camas Malag the clinopyroxene of the lens is more strongly coloured and zoned with a central core showing $\gamma \wedge c = 60°$ and a narrow periphery, deeply coloured, almost straight extinction, optically negative, and having the properties of aegirine. The pleochroism of this aegirine is a and β = grass green, γ = brown green. Strong dispersion of the optic axes, $\rho > \nu$. These pyroxene crystals have completed their crystallization at a late stage, being moulded on the microperthite. The plagioclase associated with the orthoclase has a composition close to Ab_{97} (sections normal to the obtuse bisectrix give $\beta \wedge 010 = 15°$).

This rock and its separated clinopyroxene have both been analysed, the analyses being set down in Tables 1 (No. 3) and 2.

Besides clinopyroxene, some specimens of the lens, particularly those more remote from the contact (e.g. one 24 inches from the lower contact) contain scattered grains of arfvedsonite, sometimes enclosing the clinopyroxene. This arfvedsonite has the following pleochroism : a blue, bluish green, β blue, γ brownish, greenish brown. The sections do not extinguish in white light, and in sodium light yield values of extinction of $a \wedge c = 35°$.

This description of the alkali granite can be compared with that of the normal granite from the same locality. The chief ferromagnesian mineral is brown biotite, with subordinate brown green hornblende. The felspars are microperthite and plagioclase, the latter subidiomorphic, medium grained rising to 3 mm. in diameter, and having the composition of oligoclase (An_{25}). Accessories include magnetite, apatite, and a little orthite.

Two analyses of closely similar granites from Kilchrist are set down in Table 1, Nos. 1 and 2 for comparison with that of the alkali granite already noted (Table 1, No. 3). The analyses of the normal granite, though somewhat more siliceous and poorer in iron oxides, show close resemblance to that recorded by Harker elsewhere in the Red Hills, at Druim Eadar da Choire.

The alkali character of the clinopyroxene granite is revealed in the high combined alkalis and low lime. Mineralogically, this is expressed in the abundant alkali felspars and in the nature of the clinopyroxene, which the separate analysis in Table 2 indicates as an aegirine hedenbergite. The norm of the rock shows the presence of acmite and wollastonite, pointing to a deficiency of alumina in relation to alkalis and to low values of FeO and MgO. The mode has been calculated

Table 1

	1	2	3	4	5
SiO_2	73·99	74·88	75·33	71·23	71·20
Al_2O_3	13·02	12·73	11·88	14·43	14·35
Fe_2O_3	0·76	0·53	0·43	1·10	0·61
FeO	1·60	1·33	0·95	0·66	0·89
MnO	0·02	0·02	0·01	0·03	0·02
MgO	0·31	0·25	0·08	0·26	0·25
CaO	1·22	1·12	0·92	0·97	1·34
Na_2O	3·43	3·33	2·55	4·90	4·47
K_2O	4·74	4·99	7·18	6·04	6·41
H_2O +	0·22	0·79	0·23	0·11	0·02
H_2O −	0·14	0·16	0·06		0·14
TiO_2	0·32	0·18	0·06	0·36	0·35
P_2O_5	0·05	0·05	0·08	0·07	0·16
CO_2	—	—	—	—	0·11
	99·82	100·36	99·76	100·16	100·32
Sp. Gr.	2·62	2·625	2·596		2·60

Norm	1a	2a	3a	4a	5a
Quartz	32·28	32·94	31·41	18·72	18·98
Orthoclase	27·80	29·47	42·47	35·58	37·92
Albite	28·82	28·30	21·01	40·35	37·78
Anorthite	6·11	5·00	—	—	0·11
Acmite	—	—	0·46	0·92	—
Diopside	—	0·71	3·16	1·30	2·29
Hypersthene	2·65	1·82	—	—	—
Wollastonite	—	—	0·35	1·04	0·94
Magnetite	0·93	0·70	0·46	0·93	0·93
Ilmenite	0·61	0·46	—	0·61	0·61
Apatite	—	—	—	—	0·35
Calcite	—	—	—	—	0·25
Rest	0·43	1·02	0·44	0·27	0·18
Mol. $\frac{Al_2O_3}{K_2O + Na_2O}$	1·21	1·17	0·99	0·99	1·00
Mol. $\frac{K_2O}{Na_2O}$	0·91	0·97	1·86	0·81	0·95

1. Hornblende-biotite Granite, Trial pit near granite contact, No. 1 Prospect, Kilchrist (analyst J. H. Scoon).
2. Hornblende-biotite Granite, at edge of metasomatic vein in granite, No. 1 Prospect, Kilchrist (Analyst Geochemical Laboratories).
3. Aegirine-hedenbergite Granite, contact against grossularite-wollastonite skarn, 1 mile E.S.E. of Camas Malag (loc. K.) (Analyst Geochemical Laboratories).
4. Aegirine-augite Granite, Sviatoy Noss, Transbaikalia, P. Eskola (1920), p. 72.
5. Clinopyroxene granite, vein intrusion in marble, quarries at Port Shepstone, Natal (analyst J. H. Scoon).

from the analysis of the pyroxene and the composition of the plagioclase, and is presented in Table 3. The analysis itself can be compared with that of an aegirine-augite granite described by Eskola from

TABLE 2

	1	metals to 6 oxygens		
SiO_2	49·69	1·9747 } 2·00		
Al_2O_3	0·48	0·0224		
TiO_2	0·45	0·0133 } 1·01		
Fe_2O_3	8·79	0·2626		
FeO	18·23	0·6058	Acmite	25·3
MnO	0·25	0·0084	Jadeite.	1·9
MgO	1·98	0·1172	Diopside	10·5
CaO	16·87	0·7180 } 1·01	Hedenbergite	62·5
Na_2O	3·79	0·2917		
K_2O	nil			
H_2O	nil			
	100·53			
Sp. Gr.	3·59			

1. Aegirine-hedenbergite in analysed Granite (Table I, No. 3) (Analyst H. C. G. Vincent).

TABLE 3

Aegirine-hedenbergite Granite, Skye

	Pyrox.	Or	Ab	An	Qz	Total
SiO_2	2·48	27·50	13·71	0·20	31·41	75·30
Al_2O_3	0·02	7·79	3·88	0·17		11·86
Fe_2O_3	0·43					0·43
FeO	0·91					0·91
MnO	0·01					0·01
MgO	0·09					0·09
CaO	0·84			0·09		0·93
Na_2O	0·19		2·36			2·55
K_2O		7·18				7·18
TiO_2	0·02					0·02
	4·99	42·47	19·95	0·46	31·41	99·28

Sviatoy Noss, Transbaikalia (Table 1, No. 4). Eskola has considered this rock as derived from his sviatonossites developed by reaction of granodiorite magma with limestone (or dolomitic limestone).

Petrographically, the Skye marginal granite shows great similarity too, to a rock described by Hatch and Rastall (1910) and du Toit

(1920) from Port Shepstone, Natal. Specimens of this Natal rock and its accompanying skarns are available at Cambridge and the rock described and figured by Hatch and Rastall (p. 511 and figure 2) has now been analysed for comparative purposes. The analysis is set down in Table 1, No. 5.

The rock is built of quartz, microperthite including patches and fringes of albite the composition of which is close to Ab_{97} (sections normal to (001) (010) having extinction angles of 13°). The clinopyroxene, unlike the Skye example, is not strongly zoned, but shows in places aegirine fringes. The main part of the crystals is pleochroic α grass green, γ yellowish to brownish green $c\wedge\gamma = 61°$. Sphene and apatite are accessories. In Table 4 is given a calculated mode with the calculated composition of the clinopyroxene based on the composition of the plagioclase and the allotment of Fe_2O_3 of the analysis to acmite. The calculation of the pyroxene composition can, of course, claim no great accuracy but is of interest in showing its sodic character which its optical properties attest. With that calculation may be placed the mode of the Sviatoy Noss rock, with its calculated pyroxene composition for further comparison (Table 4).

Before discussing the common features the three analyses of alkali granites possess, the environment of the Skye example calls for further description. It has already been noted that it is intimately associated with a grossularite-wollastonite skarn rather similar to that figured from Kilchrist. There the inner skarn zone is an intergrowth of grossularite and wollastonite 5–8 mm. thick, and having a composition 39 per cent grossularite, 61 per cent wollastonite, as seen from the analysis given in Table 5, No. 1. At the locality of the analysed alkali granite E.S.E. of Camas Malag, the nature of the skarn contact immediately adjacent to the granite is as follows: clinopyroxene granite | wollastonite ¾ mm. | grossularite with subordinate wollastonite 18 mm. | idocrase ½ mm. | diopside 15 mm. | marble with forsterite little phlogopite and spinel. Here no ore skarn intervenes between the diopside zone and the marble.

The chief difference between this section and that at Kilchrist is the greater width of the inner zone of grossularite-wollastonite and its much higher content of grossularite. Analyses of the diopside zones from similar specimens at Kilbride show that this mineral there possesses a significant alumina content, the dark clinopyroxene zone showing 6·42 per cent Al_2O_3 and the pale zone 3·67 per cent. Comparison of the marginal granite with that of the two analyses of normal granite shows significant features, a drop in the CaO content as well as that of FeO, MgO, and Al_2O_3. The rock clearly gives no evidence of transfer of lime by diffusion from the dolomite, or sign that mutual reaction has taken place, despite the contrast in composition.

TABLE 4

	Aegirine-hedenbergite Granite, Marble Delta, Natal										Aegirine-augite Granite, Sviatoy Noss		
	Pyr.	Or	Ab	An	Qz	Ap	Sph.	Ct	Total	Pyr.	Pyroxene	Mode	
SiO_2	2·60	24·55	24·59	0·50	18·69		0·26		71·19	50·68	50·63		
Al_2O_3		6·95	6·96	0·43					14·34		—		
Fe_2O_3	0·61								0·61	11·89	18·91		
FeO	0·88								0·88	17·15	12·46	Quartz . .	18·48
MnO	0·02								0·02	0·39	—	Microcline .	35·58
MgO	0·24								0·24	4·68	4·05	Plagioclase (Ab_{97}) . .	39·12
CaO	0·55			0·24		0·19	0·24	0·14	1·36	10·72	6·62	Clinopyroxene	5·83
Na_2O	0·23		4·23						4·46	4·49	7·33	Sphene . .	0·78
K_2O		6·41							6·41				
P_2O_5						0·16			0·16				
TiO_2^*							0·35		0·35				
CO_2								0·11	0·11				
	5·13	37·91	35·78	1·17	18·69	0·35	0·85	0·25	100·13	100·00	100·00		

On the other hand, the skarn has been enriched in alumina and silica, particularly as evidenced by the abundance of grossularite, and some alumina is also probably contained in the diopside zone beyond.

Assuming that transformation of dolomite into the skarn zones was accomplished without change of volume, it is of interest to calculate not only the material added to the skarns, but also that lost, in their development. These data are set out in Table 6 with respect to the analysed grossularite-wollastonite skarn, and for a skarn composed of pure grossularite. The chief additions, as already noted, are silica and

TABLE 5

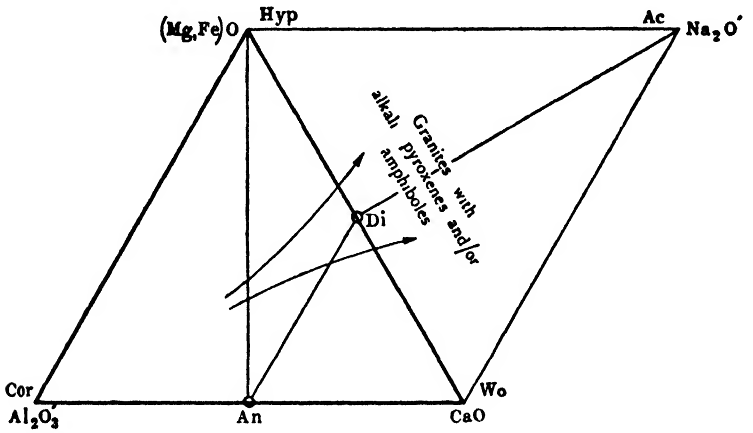
				Gain or loss in grms. per 100 c.c.	
	1	2	1a	2 → 1	2 → Gross
SiO_2	46·48			+ 147·34	+ 141·20
Al_2O_3	8·04			+ 25·48	+ 80·13
Fe_2O_3	0·92		Mode of 1	+ 2·91	
FeO	0·36		Grossularite . 38·47	+ 1·14	
MnO	0·19		Wollastonite . 60·32	+ 0·60	
MgO	0·39	21·74	Excess CaO . 0·84	− 61·16	− 62·39
CaO	43·24	30·43	Rest . . 0·62	+ 49·74	+ 44·34
Na_2O	nil				
K_2O	0·04		100·25		
H_2O −	0·02				
H_2O +	0·51				
TiO_2	0·05				
CO_2		47·82		− 137·24	− 137·24
	100·24				
Sp. Gr.	3·170	2·87			

1. Grossularite-wollastonite skarn, No. 1 Prospect, Kilchrist.
2. Dolomite (theoretical).

alumina, but they include also lime, while magnesia and CO_2 have been eliminated. There is no evidence that the eliminated magnesia has been transferred to the granite, and it is probable that it has migrated outward beyond the diopside zones. Conversely CaO, if equality of volume in metasomatism held, must have migrated inward from the limestone. These particular exchanges will be considered at greater length when the processes at work in the production of the multi-zoned skarns are discussed in a later communication.

The chemical and mineralogical data give clear evidence then of transfer of material from the magma—of silica and alumina particularly—and to this transfer must now be ascribed the petrographical change in the character of the marginal granite. The removal of

alumina in particular from the granitic liquid has led to a local impoverishment in this constituent which has had a resultant influence on the crystallization history of the marginal granite. In the calculated norm this deficiency in alumina under the molecular sum ($K_2O + Na_2O$), leads to the development of acmite and wollastonite also appears, owing to the relatively low values of $FeO + MgO$. (See Text-fig. 2.) The ferromagnesian minerals in the normal granite are both



TEXT-FIG. 2.—Plot to show effect of alumina removal from liquids of normal granitic composition (biotite, and biotite-hornblende granites) as expressed in the changing association of normative minerals. The arrow lines trace this change from the field of biotite, biotite-hornblende granites (close to the join An–Hyp) to that of the alkali granites (with alkali pyroxenes and/or alkali amphiboles. Normative compositions: Hyp (hypersthene); Di (diopside); Wo (wollastonite); Al_2O_3', normative corundum (Cor); Na_2O', femic soda (in acmite (Ac) and sodium silicate).

aluminous types (biotite and hornblende). With the changed composition these no longer appear and are replaced by a clinopyroxene, eventually bearing acmite. The modal pyroxene of the rock contains the acmite, diopside, and wollastonite of the norm, as well as the magnetite. But more than this for the plagioclase in equilibrium with the lime-pyroxene is not pure albite, but has an estimated composition of Ab_{97}. This is in harmony with the evidence of recent experimental work, which establishes that pure albite does not form from a liquid containing lime compounds (Bowen, 1945). In the case of the system albite-Ca pyroxene we may, perhaps, assume that the formation of plagioclase releasing soda follows a reaction of the type

$$2\,NaAlSi_3O_8 + Ca(Mg,Fe)Si_2O_6 \rightarrow CaAl_2Si_2O_8 + (Mg,Fe)SiO_3 + Na_2Si_2O_5 + 3\,SiO_2$$

Accordingly, in the mode more than the calculated percentage of soda

allotted to acmite in the norm is contained in the clinopyroxene (see modal composition of Table 3). A similar alumina deficiency appears in the analysis of the Sviatoy Noss aegirine-augite granite and a similar lime content is reported in the modal plagioclase. Turning now to the alkali granite from the Marble Delta, Port Shepstone, though no acmite appears in the norm it is clear that the very small amount of anorthite shown in the norm represents less than the equilibrium amount in the modal plagioclase in association with the clinopyroxene, so that an excess of soda is available for absorption in the composition of the soda-bearing clinopyroxene which petrographic examination shows is present. The calculated modal composition of both Eskola's rock and the Port Shepstone granite are set down accordingly in Table 4. The alkali granite of Port Shepstone appears as a vein or sill intrusion in the dolomites of the Marble Delta, and is surrounded by skarn zones of which two types have been described. According to du Toit, the country rock granite is a biotite (or biotite hornblende) type, and specimens at Cambridge show that in addition to microcline, oligoclase or oligoclase-andesine is present. It is to be assumed that the alkali granite now under discussion has been derived from such a type through its contact with the dolomites. The specimen analysed formed part of the intrusion figured in Hatch and Rastall, a block 3 feet in longest dimension representing the cross-section of a vein in the marble surrounded by skarn zones successively from the granite contact: (1) phlogopite-olivine (dark mica zone) 2–5½ inches, (2) phlogopite-olivine (light mica zone) 2 inches, followed by ophicalcite and normal dolomite. This environment makes evident that K_2O, Al_2O_3 and SiO_2 have been transferred to the dolomite, but as the composition of phlogopite shows Al_2O_3 molecularly in excess of K_2O, the effect on the granite is toward a deficiency again of alumina. In the second type of skarn surrounding the "soda granite" of du Toit, the zones in succession are (1) scapolite-andesine, (2) andesine, (3) phlogopite, (4) marble with forsterite and chondrodite. These zones have been tabulated from a skarn succession in a specimen presented by Hatch and Rastall, and briefly referred to in their paper (p. 514). In this association the granite has lost by transfer to the skarns Al_2O_3, SiO_2, K_2O, and Na_2O, but again under conditions leading to a relative deficiency of alumina in the magma.

Both the Skye and Port Shepstone alkali granites are thus to be considered as a product essentially of a one-way transfer of material into carbonate sediments and their composition directly related to the mineralogical character of the skarn with which they are found in contact. The removal of alumina particularly has led to the precipitation of abundant potash felspar (microperthite) with which the magma was saturated and to the appearance of an effectively non-aluminous

member of the reaction series (pyroxene) in which excess soda resulting from the alumina deficiency is incorporated. There is no decrease in the total silica in the marginal granite of Skye ; the acidity has been maintained, and it is to be assumed that diffusion to the border facies was sufficiently active to maintain a relatively high silica content. The Skye granite shows the remarkable feature in addition of very high potash compared with the normal granite. There is no evidence to suggest that this has come about by selective transfer of soda into the skarns prior to crystallization of the rock. Whatever be the case, a soda-bearing potash felspar, now microperthitic in character, has separated abundantly from the liquid. If soda was not earlier removed some has moved finally in a residual liquid into the body of the neighbouring granite. A sodic residuum is suggested by the albitic fringes to the microperthite, as detailed in the description of the rock.

We may contrast the mode of development of the Skye alkali granite with that of the aegirine-augite granite from Sviatoy Noss, already noted. At that locality Eskola has described the production of sviatonossites by reaction of granodiorite with limestone. He has considered that assimilation has operated first by the production of andradite-clinopyroxene skarns at the granite contacts, and that fragments of this skarn have been absorbed at depth and subsequently crystallized out once more, resulting in the igneous assemblage of the sviatonossites. He has pointed out that the formation of grossularite-andradite has not only effected removal of silica and ferric oxide, but also alumina from the magma, and he traces the development of alkalinity, particularly to this alumina removal, inasmuch as its incorporation in garnet and in the associated clinopyroxene has left insufficient to form felspars with all the alkalis, particularly soda present, so that part of the soda goes with ferric oxide to form acmite in the clinopyroxene.

The derivation of an aegirine-augite granite in the Sviatoy Noss region is attributed to a further differentiation of the contaminated magma. Such an aegirine-augite granite, as we have seen, resembles closely the Skye example which we have derived more directly by transfer of alumina to the skarns without the intermediate step of assimilation. The development of sviatonossites in some force in Lake Baikal district points to the adequacy of the assimilation process under favourable conditions in producing these distinctive mildly alkali assemblages, but it is remarkable that similar rocks have not been more frequently recorded. Lacroix (1922), it is true, has described from the Ampasibitika district of Madagascar, andradite-rich syenites with aegirine-hedenbergite developed by reaction of Liassic limestones with siliceous granite, but in this case the original magma, carrying riebeckite and aegirine, was itself already alkaline. Detailed investigation

of granite-limestone (dolomite) contacts elsewhere may yet reveal if processes analogous to those now discussed, whether associated with assimilation or not, have been more widely operative, and thus permit a clearer conception of their significance in petrogenesis.

Appendix

Since the above account was written, a further analysis of a marginal facies of granite in Skye has been made.

The example comes from No. 1 Prospect, Kilchrist, and is from a companion specimen of that figured in Plate I, fig. 1. The granite contains sparse green clinopyroxene identical with that already described from Kilchrist (p. 83), abundant microperthite and quartz, accessory sphene, magnetite, and an occasional grain of orthite. Albitic plagioclase never occurs as individual crystals, but only as a fine constituent of the microperthite. The granite is clearly a potash-rich type like that already described. The analysis is set down below.

The analysis closely resembles that of the marginal facies of granite set down in Table 1 (No. 3). The hand specimen from which material came for analysis contained especially close to its margin with the grossularite-wollastonite skarn, small amounts of wollastonite and botryolite, in the form of later minute venules, as well as some secondary prehnite. Examination of the material actually analysed showed that this was not wholly free from this secondary lime-rich material. The figure of CaO (1·66) in the analysis is therefore high for the granite as consolidated, and this extraneous CaO accounts for part of the normative wollastonite. Apart from this feature, the marginal granite in its petrography and chemical analysis reflects the operation of processes discussed in the body of the paper.

		Norm	
SiO_2	74·69		
Al_2O_3	12·00	Quartz	30·42
Fe_2O_3	0·44	Orthoclase	46·15
FeO	0·71	Albite	17·29 } Ab_{97}
MnO	0·03	Anorthite	0·56 }
MgO	0·12	Diopside	2·38
CaO	1·66	Wollastonite	1·85
Na_2O	2·02	Magnetite	0·70
K_2O	7·78	*Sphene	0·39
H_2O+	0·17	* Estimated in place of ilmenite.	
H_2O-	0·20		
TiO_2	0·14	Mol. $\frac{Al_2O_3}{K_2O + Na_2O}$	1·02
P_2O_5	tr.		
CO_2	nil	Mol. $\frac{K_2O}{Na_2O}$	2·51
	99·96		

Clinopyroxene granite, marginal facies against skarn, No. 1 Prospect, Kilchrist. Analyst J. H. Scoon.

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A Starfish from the Glass Sand of Loch Aline

By RHONA M. MACLENNAN

(PLATE II)

ABSTRACT

An impression of the actinal surface of a starfish, possibly *Calliderma*, has been found at Loch Aline, N.W. Argyllshire, in Cretaceous white sandstone which hitherto has yielded no fossils. Indistinct traces of the ambulacral groves are present, otherwise only the outline is clearly defined. Carbonaceous matter associated suggests the fossil may have been desiccated in dry sand. The sandstone itself is a marginal deposit with millet seed frosted quartz grains of which the perfect rounding is masked by outgrowths of authigenic quartz.

THE Cretaceous white sandstone at Loch Aline, N.W. Argyll, which is now being worked as a glass sand by Messrs Tennant, Sons, and Co., Ltd., is one of the most interesting deposits of Mesozoic age, preserved by the Kainozoic lavas, on the West Coast of Scotland. It was first described as an estuarine deposit by J. W. Judd in 1878. This sandstone has since attracted much attention because of its remarkable purity—a silica content of 99·69 per cent is quoted in the Geological Survey Memoir for Mull, Loch Aline, and Oban (p. 116). The most important description of this rock is contained in the interesting paper by Sir Edward Bailey on " The Desert Shores of the Chalk Seas " (1924). He finds support for his theory that the Chalk seas owed their excessive clarity to the existence of a desert zone surrounding them, in the millet seed quartz grains which occur in abundance in the equivalent of the Loch Aline glass sand at Beinn Iadain, 7 miles to the north, and at Gribun, in Mull. Sir Edward Bailey concluded that the deposit probably represented material blown into the sea from a neighbouring desert.

No fossils have been recorded from this sand, apart from the indeterminate marine shells collected at Beinn Iadain by the Survey (Mull Pre-Tertiary Memoir, p. 116). Recently, however, the impression of a starfish was found by some of the quarry workers at Loch Aline, in a block of sandstone which was being conveyed to the crusher. Mr. A. D. Noel Paton, the manager, has given me permission to record this starfish (Plate II) which he has retained in his office at Loch Aline.

The exact location of the fossil is uncertain, since the block containing it was not found *in situ*. However, the sandstone, though normally friable, is in this case quite indurated, and it is probable that it came from a hard band about the middle of the rock.

The impression is of the underside of the starfish, and when first found had some black carbonaceous powder associated with it;

sufficient of this powder remains to discolour the specimen, and emphasize the few details that remain. In the absence of the calcareous plates, by means of which fossil starfish are identified, it is not possible to compare it closely with other described specimens. The body is fairly large, with stellato-pentagonal outline, and the margin sharply defined with a steep angle. The major radius—about 67 mm.—measures slightly more than one and a half times the minor radius. The interbrachial arcs form a crescentic curve towards the arms, which taper abruptly. Little detail remains of the structures, apart from ridges and grooves seen fairly clearly in two arms (north-west and north in the plate) and indistinctly in a third (south-south-east). A central ridge, representing the ambulacral groove, runs in towards the mouth region from these three arms. Two further ridges, possibly representing the suture between the adambulacral and infero-marginal plates, border the ambulacral " groove " in the north and north-west arms. Rather indistinct traces of rectangular infero-marginal plates can be made out on the left side of the north-west arm. In so far as it is possible to assign this specimen to any described genus of starfish, it seems to resemble *Calliderma* Gray more closely than other figured types.

The finding of the starfish has naturally excited interest amongst the mine-workers, but so far no further fossils have been found, despite a very considerable weekly output of sand. Hence it is inviting to speculate on this solitary starfish, and an examination of the sand grains seemed worth while.

The purity of the sandstone is quite exceptional. Heavy minerals are almost non-existent ; I have seen only occasional ragged flakes of white mica, one crystal of tourmaline, several rounded and polished grains of limonite, and a black opaque mineral. The quartz grains include an occasional rose-quartz. Bearing in mind the aeolian qualities of this sand elsewhere, similarities may well be expected here. When the grains are examined dry, there is no trace of wind action. The quartz grains have a clear glassy lustre, their moderate rounding is due to conchoidal fracture, and many bear undamaged crystal facets and little pyramids. When, however, the grains are mounted in Canada Balsam, facets and angular edges " disappear ", and the grains appear to be perfectly rounded and have frosted surfaces. Practically every grain has an irregular deposit of water-clear secondary silica, and each one examined, down to 0·15 mm., is a millet seed with frosted surface.

The grains are well graded ; roughly 46 per cent is about 0·29 mm. or slightly more, and 42 per cent lies between 0·25 and 0·21 mm. Although dust seems abundant there is only 0·8 per cent of the total weight under 0·15 mm.

Wind has obviously played an important role in the formation of this sandstone. Silicification probably occurred at a later date, when

the chalk of Beinn Iadain was silicified. It may be normally supposed that the starfish gives definite proof that the sandstone was finally deposited in water ; and certainly the presence of mica flakes and a proportion of silica dust might seem to support this theory. An element of doubt must still be present, nevertheless, for not merely can a little fine material be trapped in desert sands (perhaps when the winds are gentle for a period) but a starfish, stranded by the tide, can be blown up the beach. It is possible that this starfish, preserved as an impression, without calcareous plates but with carbonaceous material associated, may have been mummified in sand just above sea-level.

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PLATE DESCRIPTION

The starfish preserved as an impression of the actinal surface in the Loch Aline glass sand. Almost flat lighting has been used, slightly stronger from the north-west to bring out the details. The relief is not so strong as the photograph suggests ; it is partly emphasized by the traces of carbonaceous discoloration. × $\frac{8}{9}$.

A Starfish from the Glass Sand of Loch Aline

Notes on the Nile Valley in Berber and Dongola

By K. S. Sandford

Abstract

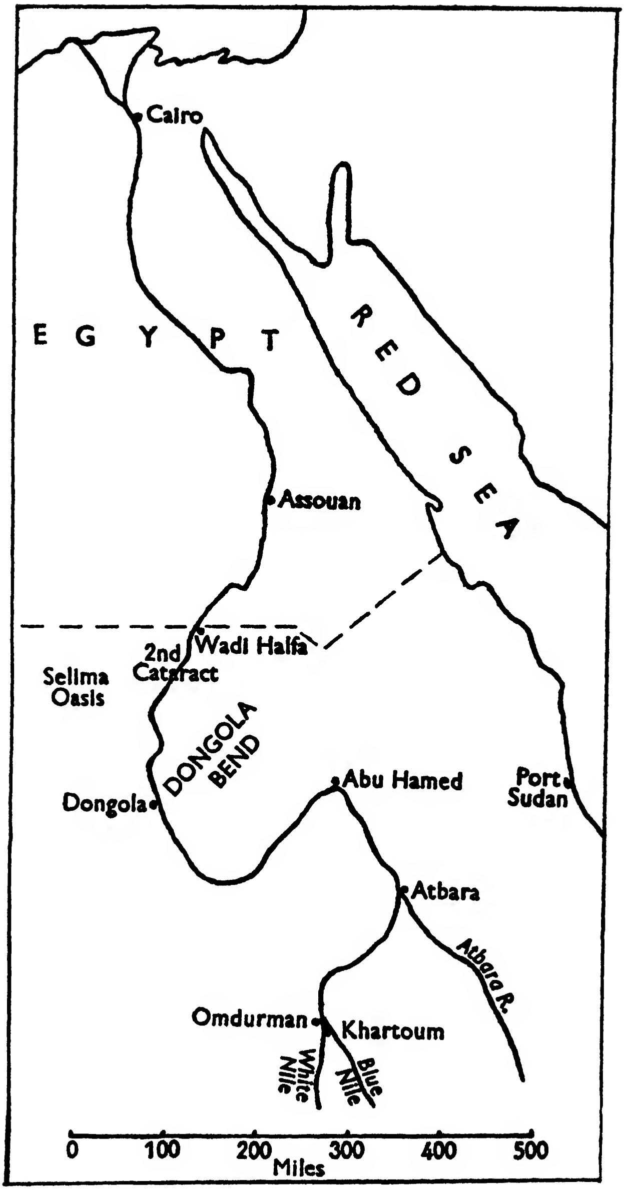
Low-lying physiographical features in the northern Sudan are associated with Lower Tertiary " lake beds ". Some undulation may have been imposed, e.g. in the Dongola bend of the Nile. There has been little vertical river erosion below the level of the lake beds in the northern Sudan, whereas in Egypt there were long successions of Tertiary sediments, uplifts, folding, and faulting. Neither late-Tertiary marine flooding nor successive regradings of the Nile in Egypt reached the Sudan. With reference to the present flood plain the summit level of some silts of Palaeolithic age rises in a striking manner from the country around Atbara (and probably a wider area) downstream into the Dongola bend, reaches a maximum (so far as known) around Wadi Halfa, and then falls again.

Introduction

Field work was done around Atbara and Merowe, between Shendi and Dongola, late in 1932, and at the time it was likely that it would be extended. Only passing reference was made, therefore, to the results (Sandford, 1933 (a) and (b), 1936 (b)). In 1935 some notes on the work were sent to the Director of the Oriental Institute, University of Chicago, the late Dr. Breasted, who had enabled me to carry out these and other field studies, and to the Government Geologist, Khartoum. They were a temporary measure, to serve until another field season might be possible, but the war intervened, and the following observations are published so that the information may be available to later investigators. For advice on the field work, for available information and for facilities in the field I am indebted to Mr. G. W. Grabham, who was Government Geologist at the time.

Physiography, and Lower Tertiary Lake Beds

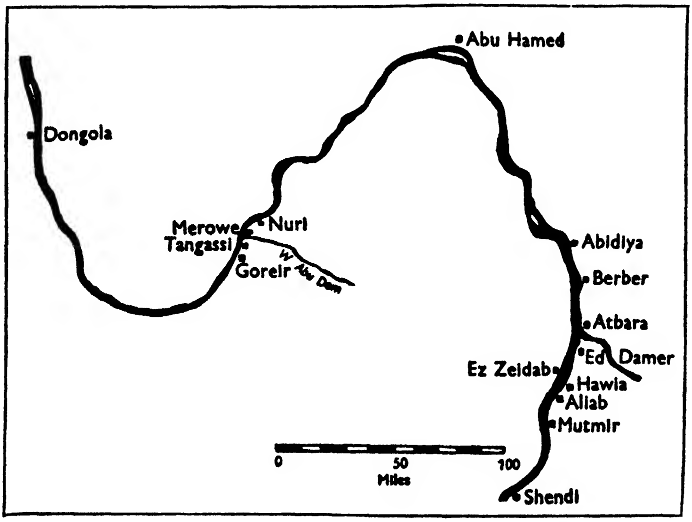
Approximately from Khartoum to Assouan (Text-fig. 1) the Nile flows through regions of Granite—gneiss—schist complex and " Nubian Sandstone " : the former give rise to broken water and cataracts, the latter mark more lethargic reaches of the river's course. In some parts, therefore, the river is engaged in active erosion of its bed in the ancient complex, imprisoned between walls of the overlying sandstones, but elsewhere it seems to have been long adjusted to the Nubian beds. Thus, its course is only about 30 metres (100 feet) below the top of some of the Lower Tertiary sediments, probably lacustrine, which lie on Nubian strata in the country around Atbara (Cox, 1932, 1933 ; Sandford, 1933 (a) ; Andrew and Karkanis, 1945). The dispositon of these Tertiary beds and physiographical evidence over a wide area led me some years ago to suppose that there are two groups of surfaces



TEXT-FIG. 1.—The Nile valley north of Khartoum.

in the northern Sudan : (1) higher, post-Nubian surfaces, represented by many isolated hills between the northern French Equatorial Africa and the Nile, locally capped with basalt ; (2) lower plains, also with basalt flows, fretting the higher tablelands, Lower Tertiary to Recent around Atbara and other riverine districts, and including much of the southern Libyan desert, which has also been modified by wind erosion.

Much work remains to be done, but it might be a fair approximation to say that the highlands are generally 600, 800 m. (about 1,970, 2,625 feet),[1] and more above sea-level, and the lower plains usually within 50 m. (164 feet) of the 400 m. (1,312 feet) contour. Andrew (Andrew and Karkanis, 1945), dealing with the chert bed of the Lower Tertiary deposits around Atbara, concludes that the lake was perhaps 500 km. (about 310 miles) wide from east to west, and 250 km. (155 miles) from north to south, and that the existence of a broad



TEXT-FIG. 2.—The Nile valley in Berber and Dongola.

plain in the northern Sudan is suggested by the disposition of the chert. Quoting G. Y. Karkanis' section on J. Nakhara, near Berber (Text-fig. 2) he shows that the lake beds are capped with basalt and remarks that the events which he describes probably preceded much of the vulcanicity, although the age of the lavas on J. Nakhara is not precisely known.

The impression that the Nile has achieved little vertical erosion in the northern Sudan, except in the cataracts, since Lower Tertiary times is strengthened by the study of gravels in the Atbara–Berber district (below), and by the discovery of Lower Palaeolithic implements in gravels about 5 m. (16 feet) above flood plain in Khor Abu Anga, 1 km. (0·62 mile) downstream of the Blue and White Nile confluence at Omdurman (Andrew and Arkell, 1943). The implements occur in ironstone gravels which, it is claimed, are of sedimentary detrital origin. They may well be so, but their value as a negation of previous

[1] All measurements from maps are given first in metres (followed by conversions into feet). Measurements in the field were made with an Abney level and are given in feet, followed by conversion to metric system.

views (Sandford, 1935) on the presence of lateritic " marram " (or pea iron ore) in the southern Libyan desert is a matter of opinion. I indicated many years ago (1936 (a)) that the period of " lateritic " climate was early and has not recurred, and such cappings are demonstrable in the areas in which they were mapped. An important paper by J. M. Edmonds (1942) concerning areas much farther south does not disprove the reality of a former climate suitable for their production : the pea iron ore may suggest rather, as do other types of evidence, (Sandford, 1936 (a)), that minor changes of climate may produce major changes of environment in a remote continental interior (Grabham, 1926), and that in the broad desert fringe of the northern and western Sudan, refinement of physiographical subdivision will be possible.

Negative evidence that the Nile has achieved little vertical erosion in the northern Sudan lies in the failure to find high level river terraces south of the Dongola bend. Flat-topped ridges in the Berber–Shendi district, especially on the west side of the river, simulate river platforms, but probably owe their contours to the bedding of the Nubian beds : the Lower Tertiary deposits occur on some of them (e.g. Ez Zeidab and J. Nakhara). Denudation of conglomerates in the Nubian beds provides gravels which may be deceptively like river gravels, but Grabham had pointed out that pebbles of agate and cherts, derived from the Lower Tertiary beds, indicate true Nilotic material ; he found them to be prominent (as much as 20 per cent of a sample) and noted them as far north as Wadi Halfa. They occur as far north as Cairo (Cox, 1933, p. 325). Nile terraces 300, 200, and 150 feet (91, 61, and 46 m.) above the river appear north of the Dongola bend and may be traced northward : Lower Palaeolithic terrace gravels are 100 feet (30 m.) above the Nile throughout Egypt.

There seems, therefore, to be a marked dissimilarity between the Nile valley upstream and downstream of the Dongola bend, so far as the altitudes of terraces and gravels, and even their occurrences, are concerned. Continuity is maintained round the great bend by some remarkable silts which, with patches of gravel beneath them, will now be described.

Old Nile Gravels and Silts and Their Ages

Nilotic gravels occur in several forms, of which two should be noted : (*a*) genuine gravels, well graded or with a certain amount of interstitial sand ; (*b*) wind-denuded concentrates of pebbles, usually small, from considerable thicknesses of silt. The latter may form prominent banks which are not, in fact, original features. Study of some 100 km. (62 miles) of the east bank, about 50 km. (31 miles) to the south and north of Atbara, and around Ez Zeidab, on the west bank, amplified

what Grabham had already observed in the field notes which he put at my disposal, namely that genuine Nilotic gravels rise to about 25 feet (8 m.) above flood plain in that stretch of the river. No fauna nor human implements were found in them. Local detail, with which these notes are not primarily concerned, can be seen south of Aliab, near Mutmir; north of Aliab, near Hawia, west of Ez Zeidab; Ed Damer (where pebbles of the chert are prominent); from Atbara, through Berber, to Abidiya (with chert sometimes abundant).

In several places they clearly pass under old silts, and at two localities, Atbara and Abidiya, instructive sections were exposed. At Atbara, gravel, forming ridges east of the town and of the aerodrome, slopes gently toward the Nile and passes under old silt: the gravel consists largely of quartz pebbles, with some of the chert, and its upper limit seemed to be 24–26 feet (8 m.) above flood plain. The continuity of the gravel below the silt was traced in a number of pits and small exposures (e.g. E.N.E. and S. of the merkaz, immediately north of the hospital, on the golf links, to the river bank). The recent alluvium of the flood plain is seen at the foot of the old silt along the river bank; and the old silt either slopes gently to the flood plain or presents a cliff of about 5 feet (1½ m.) on the one hand, and on the other thins out at about 10 feet (3 m.) above flood plain on the rising surface of the gravels.

The best section was seen in pits on the north of the hospital (Text-fig. 3) :—

3. Old silt, conforming to bedding of gravel below and filling hollows in its variable deposition: occasional strings of fine gravel: lime concretions: some gasteropods, c.f. *Melanoides*, and *Aetheria* ("Nile oyster"). Maximum of 5 feet (1½ m.).
2. Fine well-bedded gravel with rolled and unrolled *Aetheria*, some in position of growth. Middle Palaeolithic implements in place in these gravels more than 5 feet from top of section. Thickness as much as 12–15 feet (*c.* 4–5 m.).
1. Seams of coarse gravel, pebbles *c.* 6 cm. diameter, and subangular pebbles of the Lower Tertiary chert, in sandy silt with concretions: one indeterminate mineralized bone fragment. No implements. Maximum of 10 feet (3 m.). Lower beds salty and base of pit waterlogged at time of visit (December).

   The average depth of section was about 12 feet (4 m.).

Bed 1 is identified with the exposed gravel ridges of 24–26 feet (8 m.), and the various sections made clear that part of a cross-section of an old Nile bed is exposed, in which Bed 2 overlaps Bed 1 and is in turn overlapped by Bed 3: but the last does not attain the height of the marginal gravels which pass down into Bed 1.

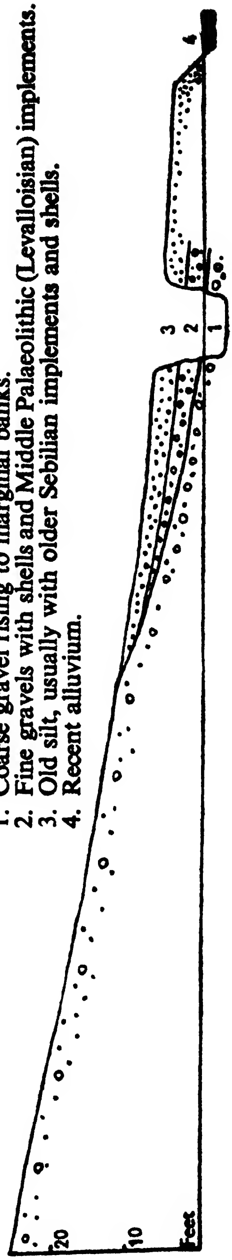
As far as I know this was the initial discovery of Middle Palaeolithic

or Levalloisian (Caton-Thompson, 1946) implements *in situ* in bedded gravels in this part of the Sudan: it was the result of J. H. Dunbar finding a specimen on the golf course.

North of Atbara the gravel ridges appear again around Berber and, as elsewhere, seem to sink stratigraphically below the old silt, with much erosional downwash over it: they are seen again north of the town, where Grabham recorded them to about 5 m. (16 feet) above the old silt, i.e. about 9 m. (30 feet) above flood plain.

Farther north, at Abidiya, the coarse gravel forms a ridge 1½ km. (0·9 mile) to the east, and sinks toward the river beneath the old silt. At the river bank coarse, highly polished, hard-set gravel is seen in a prominent bank, and polished Middle Palaeolithic implements are associated with it. The top of the coarse gravel coincides with the modern flood plain water mark (there being no alluvium at this point), and in my opinion it is a continuation of the eastern ridges under the same circumstances as at Atbara. Grabham records pebbles to 10 cm. diameter at the station (river bank). The old silt mounts to about 14 feet (4½ m.) above flood plain here, and the gravel ridges rather higher.

From these records it seems clear that in the 100 km. (62 miles) reach of the Nile described above old Nile gravels rise to a marginal height of 24–30 feet (7–9 m.) above flood plain, but no implements have yet been found in them: their continuation is traced in cross-section, and they are followed there by gravels containing Middle Palaeolithic (Levalloisian) flakes.



1. Coarse gravel rising to marginal banks.
2. Fine gravels with shells and Middle Palaeolithic (Levalloisian) implements.
3. Old silt, usually with older Sebilian implements and shells.
4. Recent alluvium.

TEXT-FIG. 3.—Sketch section of gravels at Atbara.

Everywhere such gravels are covered by old silt, the upper limit of which is above the reach of any present Nile flood: it is irrigated

locally by pumps and is a prominent feature along the Nile, sometimes forming wide plains and providing the bed of the rail track over long distances.

Thus, from the south of Aliab to the mouth of the Atbara River there are considerable plains to about 10 feet (3 m.) above flood plain east of the Nile, and the silt occurs similarly on the west bank around Ez Zeidab. Sections are fairly numerous, especially in shallow cuttings along the railway. For example, at Ed Damer sandy silts with fine quartz gravels are exposed, and can be traced eastward, where the contemporary river course seems to have lain. Palaeolithic implements of older Sebilian type, i.e. known in Egypt to be stratigraphically and typologically younger than the Middle Palaeolithic (Levalloisian) flakes already mentioned, are conspicuous features not only on the surface of the silts around Ed Damer and throughout the 100 km. (62 miles) of river bank here described, but they occur *in situ* in the silts themselves.

The silts, with their implements, are well seen north of the mouth of the Atbara River, with summit levels approximately 10–14 feet (*c.* 3–4 m.) above flood plain : Berber is built on them : there are extensive plains around Abidiya : everywhere the silts are characterized by small concretionary lime pellets. They may be seen at intervals, with the same features, northward to Abu Hamed and into the region of cataracts downstream of it, and for this reason the deposits were sought in the Dongola bend of the Nile, on the left bank, up- and down-stream of Merowe. A special problem was presented here by the entrance of a tributary, the wadi Abu Dom which, though normally dry, flushes occasionally, and I was invited by Mr. Grabham to look into the resulting conditions.

It was evident that the old silt constituted a prominent feature, and that it contained older Sebilian implements, lime pellets, small polished pebbly gravel, pebbles of Lower Tertiary chert, as in the country around Berber. It is, in fact, displayed in dusty plains with cliffs, and is much dug over for some miles upstream of Merowe, forming a marked topographic feature at a general level of about 20 feet (6 m.) above flood plain. But close inspection shows that the deposits rise to 55 feet (17 m.) above flood plain, especially in the district of Nuri, where they form a marked upper platform. A typical section here is :—

4.	Mud and pebbly surface,	10 feet	(3 m.)
3.	Grit cemented by lime, with casts suggesting reed stems,	4 feet	(1 m.)
2.	Polished gravel and sand, travertine,	10 feet	(3 m.)
1.	" Lake beds " with sticks, mud, and travertine ; *Aetheria*. Rolled implements marked here and in underlying interdigitating gravel : exposed,	10 feet	(3 m.)

Remainder of section above flood plain concealed.

It might be supposed that the high level of the silt was due to damming by an incoming tributary (the Abu Dom). Indeed, large sums have been spent on training works to deflect its occasional flood waters from Merowe and to reduce damage to land. The floods have destroyed the works, nevertheless, and recent thick accumulation has taken place round some of them only to be eroded by subsequent torrents : the wadi breaks through the full thickness of the old silts. A traverse immediately on its downstream side revealed first a low-lying, partly irrigated mud-flat, largely silt derived from the Abu Dom. The old silt can then be traced to a height of 36 feet (11 m.) above flood plain, with a flat of 20 feet (6 m.). Much of the ground has been dug over and it is clear that the silt is typically Nilotic, and not a product of the wadi ; it contains the usual pebbles, lime pellets, reed-like tubes, rolled and unrolled older Sebilian implements, and it is locally cemented by lime. Beside the wadi, gravel moved during spates, containing pebbles of pumice derived from a volcanic area in its upper course, lies on the white pellet and silt beds.

Downstream of the Abu Dom's mouth, near the ruins of the pyramids of Tangassi, there are low gravel mounds, with rolled implements of the same type as those in the silt, and patches of coarse Nilotic gravel with pebbles of Lower Tertiary chert : they are to be distinguished here from other gravel ridges which are no more than Nubian quartz pebble beds *in situ*. Finally, at Goreir, a little further downstream, an isolated ridge (visited at the pumps) proved to be 55 feet (17 m.) above flood plain. It consists of sandy river silt, with small pebbles concentrated near the top, is full of concretions of lime and sticks, contains some freshwater shells (species of *Corbicula* and *Unio* were noted) and fragments of black bone. Older Sebilian implements occur in sandy silt at and near the top, mostly on the slopes, and in fine beds. Pebbles of pumice from the Abu Dom are included.

From here upstream to Nuri there is a mud flat about 3 feet (1 m.) above flood plain, sometimes wide, marking deposition after extensive vertical erosion : the newer silt resembles the old but contains only very small limy bodies, often none at all, and no stone implements were found in it.

The following conclusions may be made from the field work in the Merowe district :—

1. The incoming of the wadi Abu Dom did not pond up the river effectively, because the old silt is found at the same height above flood plain both up- and downstream of its mouth.
2. The silt is identified as the same as that in the district around Atbara, but its altitude above flood plain is much greater. As around Atbara, it descends at any rate as low as present flood plain levels.

3. The gravels with Middle Palaeolithic (Levalloisian) flakes around Atbara (beneath the silts there) are not yet identified around Merowe, nor are the coarse gravels without implements.

The negative evidence is probably unimportant, because my visit occupied only two or three days, and much detailed field work remains to be done.

4. The upper parts of the silts around Merowe are represented by isolated ridges and hummocks, there has been much erosion, and the platform occasionally at about 20 feet (6 m.) is probably no more than a stage of denudation, possibly due to concentration of sand and small pebbles by wind erosion at this point: dust, blown from the silt, particularly where the surface is broken, is extensive.
5. The low-lying silt surface, at about 3 feet (1 m.) above flood plain is a feature of some interest; it may or may not be identifiable with the usual expanses of low-lying alluvium along the Nile and Atbara River, and its relationships to a Nile channel, now buried, such as has been proved at Khartoum (Andrews, 1912), and to deposits of the Blue Nile (Grabham, 1938) are unknown.

The most significant result, coupled with the finding of implements in the deposits, is the indication that with reference to the present flood plain as datum, the general upper level of the old silts rises downstream, coupled with the fact that in the Second Cataract and around Wadi Halfa the silt, with the same assemblage of implements, lime pellets, and fossils (so far as known), reaches a height of 100 feet (30 m.), and then falls steadily northward till it passes beneath the present flood plain in Middle Egypt. It is therefore an important unit in the study of the river from Khartoum to Cairo.

Moreover, so far as I know, the silts and some accompanying gravels are the oldest alluvial deposits of the Nile within the Dongola bend, and I am reminded of an impression—it is no more—gained in the field some years ago, particularly between Selima oasis and the Nile, that formerly the course of the river lay to the west of the present region of cataracts upstream of Wadi Halfa, and it is possible that the higher terraces may be found there. I had hoped to continue these studies in which my wife had taken part, downstream from Merowe; and to traverse the country, particularly on the west side, in a field season which is now, perhaps, unlikely to take place.

The Old Silts as a Physical Problem of Nile Hydrology.

The implications of the observations around Atbara and Merowe on river studies upstream along the Atbara River, along the Nile to Omdurman, and in the Gezira (between the Blue and the White Nile), can be omitted from these notes because they are at the moment mainly of interest within the Sudan, where they can be related to the

review by Andrew (1944) contained in the Soil Conservation Committee's Report.[1] Moreover, a contrast of climate and river history in the plains and cataracts of the northern Sudan with those of Upper, Middle, and Lower Egypt has already been analysed elsewhere (Sandford, 1936).

But so far as the Nile is concerned the African climate is indeed an obvious intrinsic factor, because it governs run-off, velocity, and volume of the river and its tributaries ; there are striking evidences of changes from the transportation of coarse material to the movement of little more than silt, such as is carried to-day.

How, then, is the peculiar behaviour of the old silt from the region of Atbara (and farther south) northward into Egypt to be explained? It appears to be the product of a circumscribed event, with essentially similar lithology, human implements, and (probably) fauna throughout its distribution. Perhaps it is significant that it is comparatively low-lying in the lowlands upstream of the Dongola bend, where maybe, there was plenty of room for it. It rises in the locally restricted courses of the Dongola bend and reaches its greatest known thickness and height above present flood plain at and near the exit from the difficult region of the Second Cataract, at Wadi Halfa where, again locally, there was plenty of room for it. Its steady fall thence northward might be related to the ultimate base level of the Mediterranean.

It is unlikely that the velocity of the silt-bearing waters differed appreciably from that of the Nile flood of to-day : if it had been much greater substantial gravels would have been formed, which generally is not the case : if it had been much less, mud in suspension might have been moved, but the sand and grit, dependent on velocity, might be hard to explain. The accumulation is most extensive where the available depositional area was broadest, i.e. much of the silt was swept into embayments and backwaters.

In short, the material was the aggraded product of a silt-carrying river, in a part of its course which was remote from any effect of a change in an ultimate base level. It could be explained by a depression of the Dongola bend—the river grade remaining much as it is to-day and the deposit being thickest where depression was greatest : but there seems to be no other evidence to support such a suggestion, nor would it account for high-lying silt in Egypt. Increased run-off would involve increased velocity in restricted cross-sections with a deeper river : decreased run-off for a given load might lead to aggradation and is in harmony with the general tendency of contemporary climate of the region, so far as known ; increased load for

[1] See also J. D. Tothill, The Origin of the Sudan Gezira Clay Plain, *Sudan Notes and Records*, XXVII, 1946, pp. 153–184, which has come to my notice after the text went to press.

a given velocity would have a similar effect. In the Atbara, Blue, and White Nile basins lie inexhaustable reserves of load, and unknown past changes in régime.

One thing seems certain : the silt is clearly similar to material which the Nile carries to-day, even if it is not so fine, and provisionally it can be judged by the same standards ; if the facts set out in these notes are correct, they can be regarded as a physical problem of Nile hydrology.

To conclude, the views set out above must be compared with those expressed by the late Dr. John Ball (1939). It would be proper to explain that I kept him posted with all available unpublished results while he was writing his book and we had opportunities to discuss some parts of it.

So far as continental stability is concerned he and I arrived at much the same conclusions by somewhat different means for all the Nilotic deposits except the low-lying beds : these he thought to be related to an isolated eastern Mediterranean, and such may have been the case. With regard to the profile of the older Sebilian silt, descending northward from 100 feet (30 m.) above flood plain at Wadi Halfa, the situation is more difficult. Ball suggested that the exceptional slope was the result of a temporary increase in the silt-content of the Nile, as a consequence of the tapping of a great lake south of Khartoum (Lake Sudd). I do not propose to discuss the hypothesis, which introduces many acutely difficult problems and unknown factors, but I believe Ball was impressed primarily by the fall from Wadi Halfa northward (as his text-figure shows), and that he did not fully appreciate that the old silt is only some 10 feet (3 m.) above flood plain around the mouth of the Atbara River, and south of it, that it rises slightly toward Abu Hamed, and strongly in the upstream end of the Dongola bend, as I have shown in these notes. The essential character, as I see it, is the rise downstream in that region, and the fall northward from Wadi Halfa, a character which I believe to be original and not the result of subsequent localized bed erosion, providing an exaggerated view of a rise of the top of the silts : the old deposits descend into the present channel and their base is rarely seen, so a channel had been cut, it was filled with silt, and through the silt the river has lowered its course.

Pliocene Marine Beds and Later River Deposits as Evidence of Continental Stability

In Egypt three stages must be contemplated, and in their broadest terms they are as follows :—

(1) Cretaceous to Miocene marine sedimentation, including Upper Eocene–Oligocene freshwater beds : mainly the products of a broad sea retreating northward. Most of the sediments are still flat-lying.

(2) Pre- and post-Miocene general elevation, faulting, and flexures, *mainly* along N.–S. and N.E.–S.W. lines (Hume, 1930).

(3) Late Miocene to present-day land surfaces with (Pontic) cutting of a deep Nile valley and tributaries, subsequent various phases of filling up and re-excavation.

From (1) it follows that the presence of a supposed *Pinna* (Cox, 1933) in the Lower Tertiary lacustrine beds (with strong probability of Upper Eocene or Lower Oligocene age) around Atbara is not so improbable as it at first appears : i.e. *Pinna* is a marine form. Problems arise about the northward recession of scarps cut in the Cretaceous and younger marine sediments.

From (2) it should be observed that the country inside the Dongola bend is regarded as an anticlinal undulation, which the river has had to negotiate. It is logical to conclude, but it is not proved, that the surfaces with which the Lower Tertiary lake beds were related have been warped here. Was there further movement when the river cut its course, subsequently silt-filled and re-excavated, and has this any bearing on a supposition that the river had a course west of the cataracts ? I am aware of no concrete evidence.

With regard to (3), whatever differential movements there were in Tertiary times, in the Pliocene the Pontic gorge-like Nile valley in Egypt was flooded by the Mediterranean, and the summit level of the deposits, which are of unknown thickness, has maintained its horizontality somewhat below the 200 m. (650 feet) contour from end to end of the flooded valley. In southernmost Egypt and the northern Sudan there was no such gorge and there are no similar deposits, and it follows that the relief associated with the Lower Tertiary lake beds may have stood not greatly above the summit level of the Pliocene gulf.

The importance of the horizontal summit level of the Pliocene beds—and only about the apex of the Delta are isolated Nile gravel patches found above them—lies in the implication that subsequent changes of river level, represented by terraces and aggraded and degraded valley fillings (with the exception of the old silt described above) have been governed by an extrinsic factor, namely relative changes of level between the continental mass and Mediterranean sea levels. That implies that they have been influenced little, if at all, by differential movement in the coastal regions. Moreover, the older and higher terraces seem to fail in the south, and such Lower and Middle Palaeolithic gravels of the Nile as are yet known there are low-lying : thus, in the continental mass the region of greatest river activity, in the vertical plane, lies nearest the sea and the performance of the Nile might be regarded as a yard-stick by which relative changes of level between Mediterranean and stable Late Tertiary to Recent north-east

Africa might be accurately measured. The disappearance upstream of certain aggrading and degrading phases might give some indication of the duration of these phases.

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Accuracy in Geological Place-names

By R. H. Rastall

Abstract

In the interests of accuracy and practical convenience, a detailed account is given of several instances well known to the author where vague or badly chosen place-names have given rise to uncertainty or even definite errors, in the position of geological localities, including one recent description of an important deep boring in N.E. Yorkshire. Attention is also drawn to an increasing looseness in the definition of the ancient local name of Cleveland. Trouble has also been caused by the recent invention of a new place-name, Ravenscar, which is synonymous with the ancient name, Peak (not The Peak, as often written by geologists). When an author is not himself thoroughly conversant with the place-names of his district it is recommended that some local authority, not necessarily a geologist, should be consulted.

As a corollary to a recent appeal by Mr. Percy Evans for greater precision in the use of geological maps, I venture to set forth some examples, derived from personal experience, in which the employment of badly chosen or imperfectly defined place-names has led to trouble or ambiguity. These examples are all chosen from my native district of North-East Yorkshire, which, of course, I know best in detail, which possesses a very large geological literature, and is in reality a classical area in stratigraphical geology, as witness for example William Smith's geological map of Hackness.

In this district there are two recent deep bores, which have lately been described in considerable detail. The name of the older of them has now, I think, definitely settled down as Aislaby, after a false start. It was at first described as in Eskdale, which was true, but much too vague, as Eskdale is a valley 20 miles long. It also led to the unfortunate result that in at least one publication of the Geological Society of London the bore was referred to as "at Eskdale" which, of course, is ridiculous. The site of the bore is actually about a mile from the village of Aislaby and as there are two villages of that name, about 20 miles apart, a perfectly correct and suitable description would be "Aislaby in Eskdale".

The case of the other boring is more difficult. It is officially referred to in the literature as in the Cleveland Hills, which is altogether too vague to help anyone who does not know beforehand where it actually is. The site is a little to the west of Bilsdale, which is a very long valley and the nearest place with a definite name is Chop Gate, pronounced Chop Yat, which is a tiny hamlet consisting of little more than an inn, long famous for "real Yorkshire ham-and-egg teas". However, this name would have been fairly well adapted for the bore, as at least giving an approximate position findable on a map.

Now the use of the term Cleveland Hills itself involves many

difficulties, partly due to the considerable extent of the said hills, partly to the want of any authoritative definition of them, and partly to a gradual change in the application of the name Cleveland in geological literature. Taking the last point first, the trouble seems to have begun with Professor Kendall's classical paper on Glacial Lakes in the Cleveland Hills, because only a very small proportion of the country covered by that paper can possibly be described as in the Cleveland Hills. Nevertheless many geologists without local knowledge got the impression that Cleveland includes the whole of the moorland area, east to Scarborough and south to Pickering and Helmsley. It is a misfortune that the old name " Blackmoor " for the southern half of this region has entirely gone out of use. I have not heard it spoken for over fifty years. If still current it could have been extremely useful in geology.

A strict definition of Cleveland is not easy for the general reader. It is probable that the best delimitation can be obtained from the map in Ord's *History of Cleveland* (1843). Although this book contains many errors, historical and otherwise, the author presumably knew the boundaries of his area. Two points of importance are quite clear : the eastern boundary of Cleveland is at Eastrow Beck, about three miles west of Whitby, while the southern boundary is the Esk-Rye watershed westwards from about Goathland. This leads to the curious paradox that only half of the anticlinal Cleveland uplift is in Cleveland, as the watershed is the crest of this uplift. When interpreted strictly according to this criterion it turns out that the Cleveland Hills boring is not in Cleveland, being slightly south of the watershed.

Now as to the definition of the actual Cleveland Hills there is much discrepancy of opinion, and in most published maps there is something to object to. Even in the most recent publication of all, the Regional Handbook of the Geological Survey on *East Yorkshire and Lincolnshire*, in some of the maps the name Cleveland Hills is so placed as to exclude their most typical, characteristic, and spectacular feature, Roseberry Topping—the Othenesberg of the Norsemen who first named their *Cliff-land*, which name (= Odin's Hill) shows what *they* thought of it. The Norse name Cliff-land at any rate seems to imply that the Cleveland Hills extend to the sea, where Boulby Cliff, the highest on the English coast, towers over everything else, in spite of great damage from alum workings.

Another very common error, which it seems impossible to eradicate, in spite of repeated protests is writing " The Peak " for Peak, between Robin Hood's Bay and Scarborough. The name Ravenscar, which is practically synonymous, is in reality a modern fake, due either to a land company or the North-Eastern Railway. The name Blea Wyke simply means " blue creek " and an early author who received a severe

snub from authority for writing " Blue Wick " was in reality perfectly correct, *wick* and *wyke* being synonymous. People who know this coast derive much amusement from twaddle about Vikings as sea-kings: the word simply means " dwellers in the creeks ", and has nothing to do with any sort of king. But this is not geology.

Now the object of all this discussion of local detail, which readers, if any there are, will probably find tiresome, is just to suggest that authors writing papers and choosing place-names in districts that they do not know intimately, would as a rule do well to consult some local authority, not necessarily a geologist, as to such choice and definitions, as there are many pitfalls in local names. I do not for a moment suggest that the district here discussed is worse off than many others in this respect.

Finally a very brief but pointed anecdote: a museum palaeontologist once gave the locality of a fossil, without any place-name, as " four miles north of Ribblesdale ". Surely he took the prize for vagueness. As Ribblesdale is about forty miles long and runs north and south, further comment is hardly necessary. People in the south of England do not seem to know what a *dale* is.

Ranikothalia in East and West Indies

By L. M. Davies (Grant Institute of Geology, University of Edinburgh)

Abstract

The author emphasizes the distinction of the marine Paleocene fauna of India from that of Europe, and its resemblance to that of the West Indies (Antilles). He suggests a marine connection between West and East Indies across North Africa, south of the Mediterranean region, in basal Tertiary times, before the Americas had drifted far from Europe and Africa.

The Indian Paleocene Fauna

It is a striking fact that while the Maestrichtian (or Dunghan, *s. str.*) foraminiferal fauna of North-West India definitely corresponds with that of western Europe (*cf.* L. M. Davies, 1941), and while the Lutetian (or Kirthar) fauna of North-West India again closely resembles that of Europe, the intermediate Paleocene (or Ranikot) fauna of North-West India is very different from its contemporary counterpart of the Mediterranean region (*cf.* L. M. Davies, 1927, 1937, 1940). This seems to indicate that, after losing its contact with European waters during the great marine regression of Danian times (marked by the Hangu Sandstone of North-West India ; *cf.* L. M. Davies, 1930, p. 9 ; 1943, p. 65 ; etc.), the Indian region did not regain that contact until after the Paleocene—during which its communications were with some other region, or regions.

Nummulites nuttalli and its Allies

It is therefore worth noting that the most important member of the Indian Paleocene foraminiferal assemblage is the species *Nummulites nuttalli*/*N. thalicus*, which is extremely variable, and merges into *Operculinoides sindensis*/*O. gwynae* on the one hand, and into *Miscellanea stampi*/*M. miscella* on the other (*cf.* L. M. Davies, 1937, pp. 40–42 ; etc.). I was not, therefore, surprised when *N. nuttalli* was adopted by Dr. C. M. B. Caudri (1943–44, pp. 17 ff.) as the type for her intermediate genus *Ranikothalia*, which she erected to link ordinary *Nummulites* (*Camerina* auctorum) to *Miscellanea* (Pfender, 1934, p. 231 ff.).

Affinities with West Indian Paleocene Types

What is more, Caudri herself (*loc. cit.*) and other workers (e.g. Cole, 1944 ; Vaughan, 1945 ; *cf.* Vaughan and Cole, 1941, and H. D. Thomas's remarks, 1946) have emphasized the existence of several species of both *Ranikothalia* and *Miscellanea* in the basal Tertiary beds of the West Indies. Among these western *Ranikothalia* is *R. bermudezi* (Palmer) (1934), which bears a close resemblance to the Indian *N.* (or *R.*) *nuttalli* itself ; and the late Mrs. Palmer told

me (letters of 10th March and 13th August, 1946) that *R. bermudezi* is not a Cretaceous form, as thought when she originally described it, but is a Paleocene one.[1] It therefore not only resembled *N. (Ranikothalia) nuttalli* but was also its contemporary. As Mrs. Palmer further remarked, there is more resemblance between the foraminiferal faunas of the Antillean and North-West Indian regions in Paleocene deposits than in later ones ; and this fact suggests that there was more direct communication between those regions at the beginning of Tertiary times than existed later. That, in turn, raises the question as to what route the communication took ; since it must have by-passed the Mediterranean region, which was occupied by a different assemblage during the Paleocene.

Togoland *Nummulites*

I was therefore much interested in collections of foraminifera from French West Africa which were sent to me by the Director of Mines at Dakar towards the end of the late war, for I found that while the material from Senegal had a Mediterranean aspect, and was mostly of Eocene age, a small consignment from the vicinity of Toffo (6° 54′ N. : 2° 2′ E.) in Togoland was full of *Nummulites* externally indistinguishable from *N. nuttalli*, and internally also similar—though to a less degree. These cannot be far removed from *N. nuttalli.*

This fact is doubly notable. In the first place, it shows that *Nummulites* appear in West African sediments south of Senegal, a circumstance not hitherto realized (*cf.* A. M. Davies, 1929, p. 316 ; also 1934, vol. ii, p. 101) ; and, in the second place, it affords some sort of link between the East and West Indies. It may be remembered that, according to the theory of Continental Drift, the Antillean region would, in basal Tertiary times, have adjoined the African coast near Togoland (*cf.* du Toit, 1927 ; Gregory, 1929 ; etc.).

Saharan Links with the Paleocene Sea of India

Did, then, communication exist across North Africa to the Indian sea ? Or did the line of communication pass southwards, round the coast of Africa ? There seems, as yet, to be no evidence that the Paleocene sea left similar deposits further south in West Africa ; but collections sent by the Director of the Geological Survey of Nigeria, from Gidan Idaltu (13° 24′ N. : 5° 18′ E.) and Hamma Ali (13° 9′ N. : 5° 18′ E.), near Sokoto and in the latitude of Lake Chad, contain foraminifera which I identified as closely related to *Assilina praespira* Douvillé (1905), and which may be a local variety of the same. This

[1] I see that Caudri (1948, p. 475, footnote 7) reports getting a similar letter (dated 26th March, 1945) from Mrs. Palmer, intimating an Eocene date for *Ranikothalia bermudezi.* But in her rather later letters to me, Mrs. Palmer narrowed matters to the Paleocene.

form is probably the one termed *Operculina canalifera* by A. M. Davies (1934, vol. ii, pp. 74, 112), as also by other workers, whose criterion for distinguishing *Operculina* from *Assilina* differed slightly from my own (1945).

This so-called *O. canalifera* seems to accompany *Plesiolampas saharae* Bather (1904); and the latter is significant, since the genus *Plesiolampas* characterizes the Upper Ranikot (late Paleocene) beds of India, and has apparently not been found in European deposits. *P. saharae* has been reported from Gao (16° 16′ N. : 0° 12′ E.), from Tenekart north of Tahoua (14° 57′ N. : 5° 16′ E.), from Tamaské (14° 53′ N. : 5° 49′ E.), from Garadimi (14° 20′ N. : 5° 50′ E.), and from near Zinder (13° 45′ N. : 8° 57′ E.), etc.; while *P. pacquieri* Lambert (1906) is also found near Gao and Tenekart. As linking these with India, De Lapparent (1903) notes the finding of *Plesiolampas* in Egypt. Moreover, an echinoid described by Gauthier (1901) as *Noetlingia monteili*, of late Cretaceous age and showing Indian affinities, has been found a little south of Bilma (18° 37′ N. : 13° 22′ E.). It seems possible, therefore, that a westward-extending arm of the Indian sea traversed the Saharan region of North Africa in late Cretaceous and basal Tertiary times (*cf.* also De Lapparent, 1901; Cottreau, 1908; Lambert and Pérébaskine, 1929; etc.).

It will be interesting to see if further discoveries tend to confirm this suggestion; and, in any case, there is no doubt that considerable affinity exists between the Paleocene Nummulitoidea of the East and West Indies, with some apparently linking forms in North-West Africa, a good deal south of the Mediterranean region.

I note that Mme. De Cizancourt now (1948) treats both *Ranikothalia* and *Miscellanea* as synonyms of *Nummulites*, owing to the difficulty of clearly separating these forms in the basal Tertiary beds of the West Indies, much as I emphasize their merging in the Paleocene beds of North-West India. Apparently, this very able worker tends to "lump", and Caudri and I to "split", in the matter of terminology, while the facts themselves are unmistakable.[1]

[1] Mme De Cizancourt allows that forms without a marginal cord—and its correlated "canal system"—might be distinguished as *Miscellanea*; but the final disappearance of that cord is only the last stage in the degeneration of the outer skeleton. The cord still appears, in every intermediate degree, in specimens passing from *Ranikothalia* to the more extreme *Miscellanea*. So note that a very perfect specimen of American *Miscellanea* was figured by Hanzawa (1937, pl. 21, fig. 5) as *P. matleyi*. Observe the complete absence of marginal cord in this individual; and also the clubbed tops to its pillars—a feature often appearing in Indian *Miscellanea*.

Mme De Cizancourt is emphatic (1948, p. 31) that: "Les Nummulites de la Barbade s'écartent notablement des types habituels, mais par contre possèdent un ensemble remarquable de caractères communs avec les Nummulites du groupe de *N. nuttalli*, du Ranikot des Indes." These latter are, of course, Caudri's *Ranikothalia*.

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Dyke Phenomena of the Dicq Rock, Jersey, C.I.

By M. CASIMIR and FREDERICK A. HENSON

(PLATE III)

ABSTRACT

The granite of the Dicq Rock is traversed by several veins of fine grained aplogranite. These in turn are cut by a large dolerite dyke, which has been intruded into a brecciated fault zone within the granite. Three large blocks of granite occur within the dolerite ; these originally formed the southern boundary of the fault. The petrography of these rocks, and the influence of the micro-breccia upon the textures found in the marginal and central part of the dolerite, are considered in detail.

INTRODUCTION

ALTHOUGH numerous dykes, varying in width from a few inches to over 20 feet occur amongst the igneous rocks of Jersey, they have as yet received little attention. The Rev. C. Noury (1886), in his admirable monograph, devotes a chapter to dykes only, giving a general description of their occurrence. Smith (1933–36) published three papers dealing with the mica lamprophyres only.

The dykes are magnificently exposed along the coast, inland they are well exposed but deeply weathered. It is not unusual to find that dolerite dykes cut aplitic veins, although this is not always the case, and are themselves traversed by the mica lamprophyres. Of special interest is the curious mode of intrusion which some of the dykes exhibit. The aplites and dolerite of the Dicq Rock are here described in detail, their field relationships are shown in Text-fig. 1.

FIELD RELATIONS

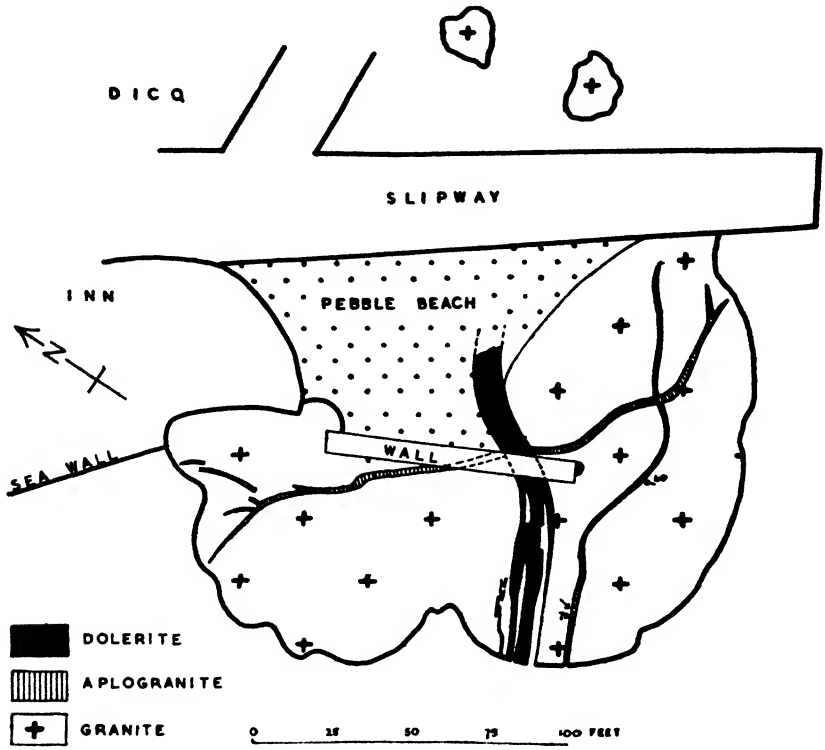
(*a*) *Granite and Aplogranites*

The Dicq Rock, which forms a large topographical feature on the coast south of St. Helier, is situated about 100 yards east of the Havre des Pas Bathing Pool. To the east of Dicq Rock stretches the beach of Greve d'Azette. The dykes concerned intrude a medium-grained porphyritic granite which contains numerous basic xenoliths.

The intrusions consist of aplogranites and a dolerite. The aplites occur both as a vein and, in the case of the later intrusion, as a dyke-like form, thick at its centre and thinning out towards its terminations. The aplogranite dyke and the dolerite intersect at a point beneath the wall (Text-fig. 1), their relative ages have been determined by excavating on the east side of the wall. At a depth of 2 feet the dolerite was revealed and proved to be younger than the aplogranite ; the contact being 13 feet from the south-eastern end of the wall. Six feet east of

the wall the contact between dolerite and country rock was revealed. At spring tides, with heavy seas, the pebble beach shifts and occasionally reveals the dykes.

The aplite vein traverses the granite in an east to west direction and maintains an average width of 7 inches. It has not a straight course ;



TEXT-FIG. 1.—The Dicq Rock, Jersey.

from the seaward end it is traceable eastwards for a distance of approximately 35 yards, tapering off towards the slipway. Viewed from the seaward end it rises to a height of 25 feet and hades to the south at an angle of 70°. The vein continues over the Dicq Rock to the other side, showing up well against the granite, where it inclines 60° north, curves, and is cut by another aplogranite intrusion.

As seen in the field, the contacts with the country rock are not chilled, but are clearly defined. The direction of the aplite dyke is N.W.–S.E. ; its course is irregular and it reaches a maximum thickness of 27 inches. Towards the north-west the dyke makes a sharp bend due west and then resumes its original direction. The dyke gradually diminishes in thickness and tapers out. Small offshoots occur, one showing echelon arrangement.

The south-eastern part of the dyke curves to the east, encloses small fragments of the country rock and cuts the earlier aplogranite vein. After a further distance of 6 yards the dyke bifurcates and tapers out.

(*b*) *Dolerite.*

The field relationships between the dolerite and granites are very clearly displayed. The general direction of the dyke is S.W.–N.E., and it is exposed, up to the wall, for a distance of 20 yards. In the field the contacts with the country rock show no chilled margins ; they are normally well defined and sharp. On the south-eastern boundary, associated with dolerite veins, a micro-breccia occurs.

On the north-western boundary of the dolerite dyke an offshoot of a 9 in. dolerite shows echelon arrangement. Three large granite blocks occur within the main dolerite dyke (Text-fig. 1) ; there can be no doubt that these three blocks originally formed the southern boundary of the brecciated fault zone into which the dolerite was subsequently intruded. The two blocks on the northern boundary appear to have been broken off from the ends of the third block, leaving a projection in the centre and have moved northwards. They have moved together slightly, perhaps only a few inches, since the distance between them is 3 inches less than the total length of the projecting part of the third block. This larger block is assumed to be *in situ*, since the dolerite tapers out to the west and terminates with a micro-breccia.

The main vertical joints of the granite cut through the dolerite and aplites, indicating the jointing is younger than the dyke phase.

Petrography

(*a*) *Granite and aplogranites*

Megascopically the granite is a mottled pink and dark green coloured rock ; its texture is porphyritic, with orthoclase crystals of 2–2·5 cm. in length, set in a medium-grained groundmass.

In thin section the principal minerals present are quartz, perthite, plagioclase, biotite, and hornblende. The granite is relatively poor in accessory minerals. Quartz occurs both in anhedral and subhedral forms. Weak undulose extinction and numerous fractures are characteristic of the quartz crystals which frequently exhibit a micro-pegmatitic intergrowth with perthite and plagioclase. Less common is the true granophyric intergrowth. Inclusions are common, and include plagioclase and accessory minerals. Perthite occurs in two forms, one in which the albite lamellae are clearly distinguished and the other in which the albite traces are irregular. Very much altered plagioclase cores occur in some perthites, whilst in others numerous quartz blebs occur as well. Microcline is rarely present. Plagioclase (oligoclase) occurs in subhedral form ; it is often partially altered to sericite.

A deep brown biotite occurs throughout in aggregates of several flakes, and is generally chloritized. Hornblende is normally associated with the biotite, and is also frequently altered to chlorite and epidote. The accessory minerals include abundant apatite, magnetite, ilmenite, fluorspar, sphene, and zircon.

The aplogranites are mottled pink and white rocks, fine-grained with local patches of dark minerals. They resemble the Fort Regent Granophyre. They are composed essentially of quartz, perthite, plagioclase, and patches of biotite, which is generally altered to chlorite. The accessories are iron ores, apatite, and zircon. Potash felspar and quartz are frequently intergrown, producing a characteristic micro-pegmatitic texture. The plagioclase present is slightly more acid than in the granite and is less altered, as a general rule, to sericite.

At its contact with the granite the newer rock is finer grained, contains less plagioclase, and does not exhibit the micro-pegmatitic texture of its central part. The contact, as in the field, is quite distinct. Near to the aplites the felspars and biotite of the granite appear to be less altered than usual to sericite and chlorite. Apatite and magnetite are abundant in one slide within a narrow zone of 0·5–0·75 cm. from the contact, the former occurring in large and well-formed crystals.

(*b*) *Marginal Dolerite and Dolerite Veins*

Thin dolerite veins, occurring on both northern and southern boundaries of the main dolerite, reveal many interesting features in thin section. In both there is evidence that the dolerite intrusion is post-brecciation. Fig. 1 (Plate III) shows the micro breccia from the seaward extremity of the southern dolerite tongue. The breccia which separates granite from dolerite varies in thickness between 1 and 2 mm ; where the dolerite tongues out it increases to 3–4 cm. Micro-breccias are not preserved along the contacts of the main dolerite, or along the granite blocks within the dolerites where the potash felspars frequently show abrupt and shattered ends.

The breccia zone contains angular granitic materials, principally quartz, perthite, magnetite, and altered ferro-magnesians. There appears to be no mixing of dolerite material in this zone, although numerous small augites often occur in abundance along the contact. Granitic material is caught up by the dolerite, and specimens have been examined which illustrate the mechanical reaction between breccia and dolerite. Firstly, the dolerite is seen embaying the breccia, this is followed by disruption, and finally the fragments, which have been broken off, are carried along in the dolerite.

The texture of the marginal dolerite is porphyritic and contains fragments of granitic material originating from the breccia zone.

There is a strong tendency for minerals to form patches, particularly the derived material, whilst the fine-grained groundmass shows distinct banding and orientation of plagioclase laths parallel to the margin. Most of the larger augites are fractured and broken. In some cases the marginal dolerites are glassy when in contact with disintegrating breccia material.

(*c*) *The Dolerite*

Macroscopically the dolerites are grey-green in colour and are extremely fine-grained considering the width of the dyke. Small felspar crystals 2–3 mm. in length can, however, be distinguished.

At its centre the texture of the dolerite varies considerably over relatively small areas. Microscopically examined the felspar laths are found to vary enormously in thickness and in length. The augite present occurs as small euhedral and subhedral crystals, penninite and magnetite are common. Scattered throughout are patches of altered granitic material—quartz, potash felspar, and biotite. Whilst the texture varies locally from sub-ophitic to intergranular, the texture of the whole is best described as glomeroporphyritic.

The quartz present occurs in small irregular and embayed fragments, which show undulose extinction and contain minute inclusions, including one flake of brown biotite showing hexagonal crystal form. Fragments of potash felspar are less abundant, in fact they are almost entirely altered to quartz and sericite. Minute fragments of brown biotite occur sporadically, whilst granular epidote occurs occasionally. Plagioclase occurs in laths and is only partially altered, X′ 010 18–22° corresponding to labradorite (An 55).

Conclusion

The igneous rocks of Jersey present many problems in the determination of their age, owing to the complete absence of fossiliferous strata in the island. The granite of the Dicq Rock is one of the older granites of Jersey, probably of Pre-Cambrian age (Wells and Wooldridge, 1931, Mourant, 1933). The aplogranites most likely represent the late stage features of the granite, occupying fissures within it, due to contraction upon cooling of the main mass. Whilst it is impossible to state the age of the fault breccia and the dolerite, it is suggested that they are of Armorican age. Recent work upon the granites of south-west Jersey (Henson, 1947) indicates an Armorican age to the granites and dolerites of this area, the latter being mainly in the same general W.S.W.–E.N.E direction as the dyke described above. Dolerites having an approximate N.–S. direction are later, being of the same age as the mica lamprophyres.

To the Research Board of the University of Nottingham acknowledgment is made of a grant, making possible the research now being carried out on the plutonic and associated rocks of Jersey (F. A. H.). Mr. R. Robinson and Major J. C. M. Manley have assisted in the field by digging and in detailed measurement of the dolerite. Their kind co-operation and assistance is acknowledged.

EXPLANATION OF PLATE

FIG. 1.—Ordinary light. × 30. Section shows the micro-breccia (0·75–1·0 mm. in width), 5 cm. from the end of a dolerite tongue. The margin of the granite shows fractured quartz and altered perthite ; fragments of these minerals form the bulk of the micro-breccia, with some chloritized ferro-magnesian minerals. Within the marginal dolerite are derived fragments of granite.

FIG. 2.—Ordinary light. × 30. Contact between granite and dolerite in the main dyke. The biotite present has been considerably altered, due to the intrusion dolerite, with the formation of octahedra and rhombic dodecahedra of magnetite. Also present are altered felspar, quartz, hornblende, apatite, zircon, and epidote.

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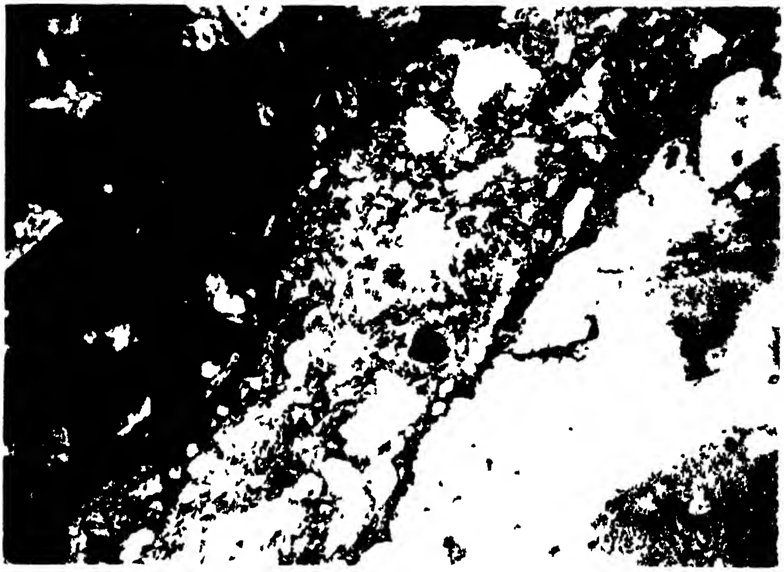
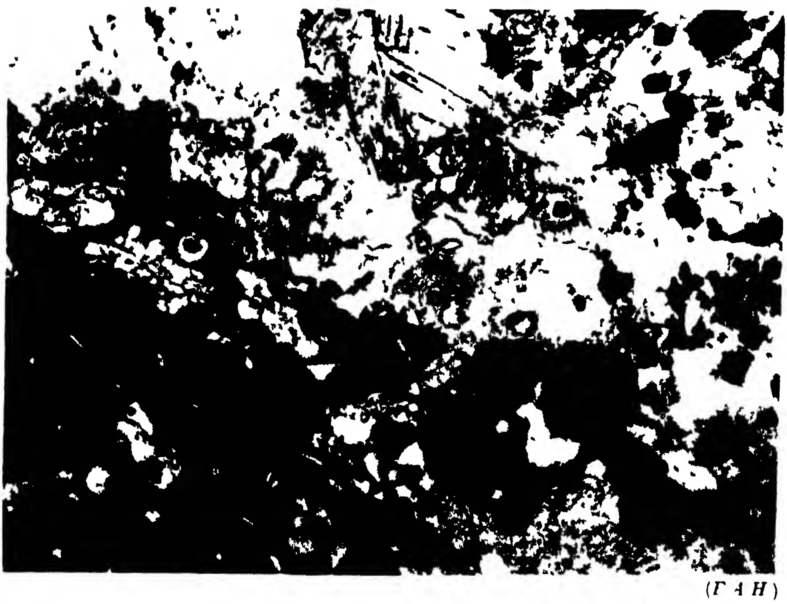


FIG. 1



(F A H)

FIG. 2

DYKE PHENOMENA OF THE DICO ROCK.

Evolution of *Delocrinus* to *Paradelocrinus*, and Description of *Stuartwellercrinus argentinei* sp. nov.

By Harrell L. Strimple

(PLATE IV)

Abstract

The transition of *Delocrinus* to *Paradelocrinus* is demonstrated by a group of specimens collected by Mr. Allen Graffham from the Iola limestone of Kansas. Description of *Paradelocrinus iolaensis* sp. nov. is given, and the geological range of the Permian genus *Stuartwellercrinus* is taken into the Pennsylvanian (Upper Carboniferous) with the presentation of *Stuartwellercrinus argentinei* sp. nov. from the Wyandotte limestone of Kansas.

Delocrinus Miller and Gurley

Delocrinus subhemisphericus Moore and Plummer

Pl. IV, figs. 8–15

A SMALL group of Delocrinids collected by Mr. Allen Graffham from the Iola limestone formation of Kansas is of unusual interest because of the tendency toward elimination of the single anal element (anal X) from the dorsal cup. Of 34 calices studied, 33 are readily assigned to *Delocrinus subhemisphericus* Moore and Plummer (1940, p. 258). There are minor variations, which is to be expected in any group of fossils, but in this instance there is a striking demonstration of progressive evolution without loss of specific identity. It is possible to readily follow the transition from *Delocrinus* to *Paradelocrinus*. Probably the ratio of normal specimens to advanced forms is somewhat distorted because all of the specimens collected at this horizon by Mr. Graffham are not available, and it is assumed the greater number of advanced forms have been retained.

The paratype figured by Moore and Plummer (1940, pl. 20, fig. 3) from the Lane shale at Kansas City is taken as a typical example—anal X rests solidly on the truncated upper extremity of post. B, well within the dorsal cup, which is termed " Normal Type ". In the selection observed, 17 specimens were found to conform to such a requirement. In 12 specimens there is no contact between anal X and post. B ; the lower extremity of the anal plate and the upper extremity of post. B both terminate in a point, yet the anal X is still an integral part of the dorsal cup and has an outer surface confluent with adjoining RR. This is termed " Advanced Type " and illustrated by Pl. IV, figs. 8–10. Four specimens are considered " Extreme Type " as illustrated by Pl. IV, figs. 11–15, in which anal X is retained only as a rudimentary element, located in a notch between the articular facets of r. post. and l. post. RR, near their innermost margins.

It is fortunate that one specimen in the selection is a distinct representative of *Paradelocrinus*, thus permitting a complete study of the evolutionary development. Description of the form is given later in this paper.

Quite probably some species assigned to *Paradelocrinus* have originated in the erisocrinids, through development of a basal concavity and a spherical outline.

Variations in *Delocrinus subhemisphericus.*

	Normal Type.	*Advanced Type.*	*Extreme Type.*
Iola limestone formation	17	12	4
Lane shale formation (after Moore and Plummer)	not given	2	0

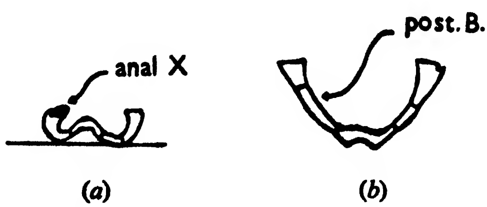
Stratigraphical distribution of Delocrinus subhemisphericus.—Moore and Plummer (1940, p. 261) give the type locality of *Delocrinus subhemisphericus* as Lane shale, upper part of the Kansas City Group, Missouri Series, Pennsylvanian, at Kansas City, Missouri. They do not report the species in collections studied from Texas. The specimens used here are from near the top of the Raytown limestone member, Iola limestone formation, Kansas City Group, at the cement plant quarry near Iola, Kansas. Moore considers the Dewey limestone formation of north-eastern Oklahoma as the probable equivalent of the Iola limestone of Kansas; however, there have been no specimens of *D. subhemisphericus* observed in the collections made by the author from the Dewey limestone.

Paradelocrinus Moore and Plummer

Paradelocrinus iolaensis sp. nov.

Pl. IV, figs. 5–7, Text-fig. 1*a*

Dorsal cup mildly pentagonal in outline when viewed from above or below. Base deeply concave; IBB five small elements, sharply downflared, and there is no angulation at meeting with BB; BB five, large elements curving evenly out of the funnel-like basal concavity;



TEXT-FIG. 1 (*a*).—Cross-section of *Paradelocrinus iolaensis* sp. nov., holotype. × 1¼ approx.

TEXT-FIG. 1 (*b*).—Cross-section of *Stuartwellercrinus argentinei* sp. nov., holotype. × 1¼ approx.

BB circlet petal shaped when viewed from below, median portion of each plate depressed so that the suture actually occupies a ridge-like raised area. The lowermost extremities of RR are prominent, articular facets slope slightly outward and are rather narrow ; outer ligament furrow is thin but well defined and the ligament pit is sharply impressed ; muscle areas are very shallow, and lateral ridges rather high. At the meeting of r. post. R and l. post. R it is seen that a narrow protuberance or extension of the r. post. R curves into the articular area. A long narrow anal plate is present in the interarticular notch behind the extension.

Columnar scar is circular in outline and very small. Arms have not been observed.

Measurements.—

	Holotype. mm.
Height of dorsal cup	4·9
Width of dorsal cup	15·0
Ratio of height to width	0·32
Width of IBB circlet	2·5
Length of BB	4·5
Width of BB	6·3
Length of RR	4·3
Width of RR	9·0
Length of suture between radials	3·3
Length of suture between basals	4·0

Horizon and Locality.—Near the top of the Raytown limestone member, Iola limestone formation, Kansas City Group, Missouri Series, Pennsylvanian, at cement plant quarry, N.E. 1/4 Sec. 2, T. 25 S., R. 18 E., near Iola, Kansas (American Pennsylvanian = European Upper Carboniferous).

Holotype.—Collected by Mr. Allen Graffham, of the University of Nebraska. To be deposited in the U.S. National Museum.

Remarks.—This species is closer to *P. dubius* Moore and Plummer than any other described species. The depression of median portion of the basal plate, protrusion of lowermost extremity of each radial and funnel-like basal cavity are all typical of the lower Pennsylvanian species and has not previously been observed by the author in middle or upper horizons. *P. iolaensis* has a shallower cup than *P. dubius.*

Stuartwellercrinus Moore and Plummer

Stuartwellercrinus argentinei sp. nov.

Pl. IV, figs. 1–4, Text-fig. 1*b*

Dorsal cup turbinate-shaped, pentagonal outline when viewed from above and IBB are readily visible in side view. Five IBB expand evenly from the cone-like depression formed by the columnar impression ; 5 BB, large, hexagonal in outline, mildly tumid ; 5 RR, large,

smooth, pentagonal in outline. Articular facets are nearly horizontal except for a slightly raised area on the left of what is assumed to be the r. post. R. There is no discernible notch or anal plate, and the projection probably served the function of such an element.

Columnar scar is mildly pentagonal in outline. Stem and arms have not been observed.

Measurements.—

	Holotype. mm.
Height of dorsal cup	7·9
Width of dorsal cup	14·0
Ratio of height to width . . .	0·56
Height of OBB circlet	1·6
Width of IBB circlet. . . .	5·1
Length of BB	4·6
Width of BB	5·9
Length of RR	4·1
Width of RR	8·6
Diameter columnar scar . . .	2·4
Length of suture between radials .	3·0
Length of suture between basals .	2·4

Horizon and Locality.—Argentine limestone member, Wyandotte limestone formation, Kansas City Group, Missouri Series, Pennsylvanian (Upper Carboniferous), near 33rd and Roanoke Streets, Kansas City, Missouri.

Holotype.—Collected by Mr. Allen Graffham. To be deposited in the U.S. National Museum.

Remarks.—The species is assigned to *Stuartwellercrinus* with reservation. As defined by Moore and Plummer (1940, p. 328) the genus has only three IBB, and the arms are unknown for any described species. *Cibolocrinus trinodus* Weller has five IBB and was assigned by Moore and Plummer (1940, p. 134) to *Spaniocrinus* Wanner (1924, p. 292) with reservation. It is quite probable the entire group will eventually be placed under *Spaniocrinus*. Presence of three IBB in these inadunates only indicates fusion which is not of generic importance in itself. The pentamerous symmetry of *S. argentinei* when viewed from above is typical of *Erisocrinus*, however, the base of that genus is flattened or mildly concave, so that IBB are not visible in side view. The mild tumidity of BB plates and shallow concavity of lower portions of RR serve to readily separate *S. argentinei* from closely related species.

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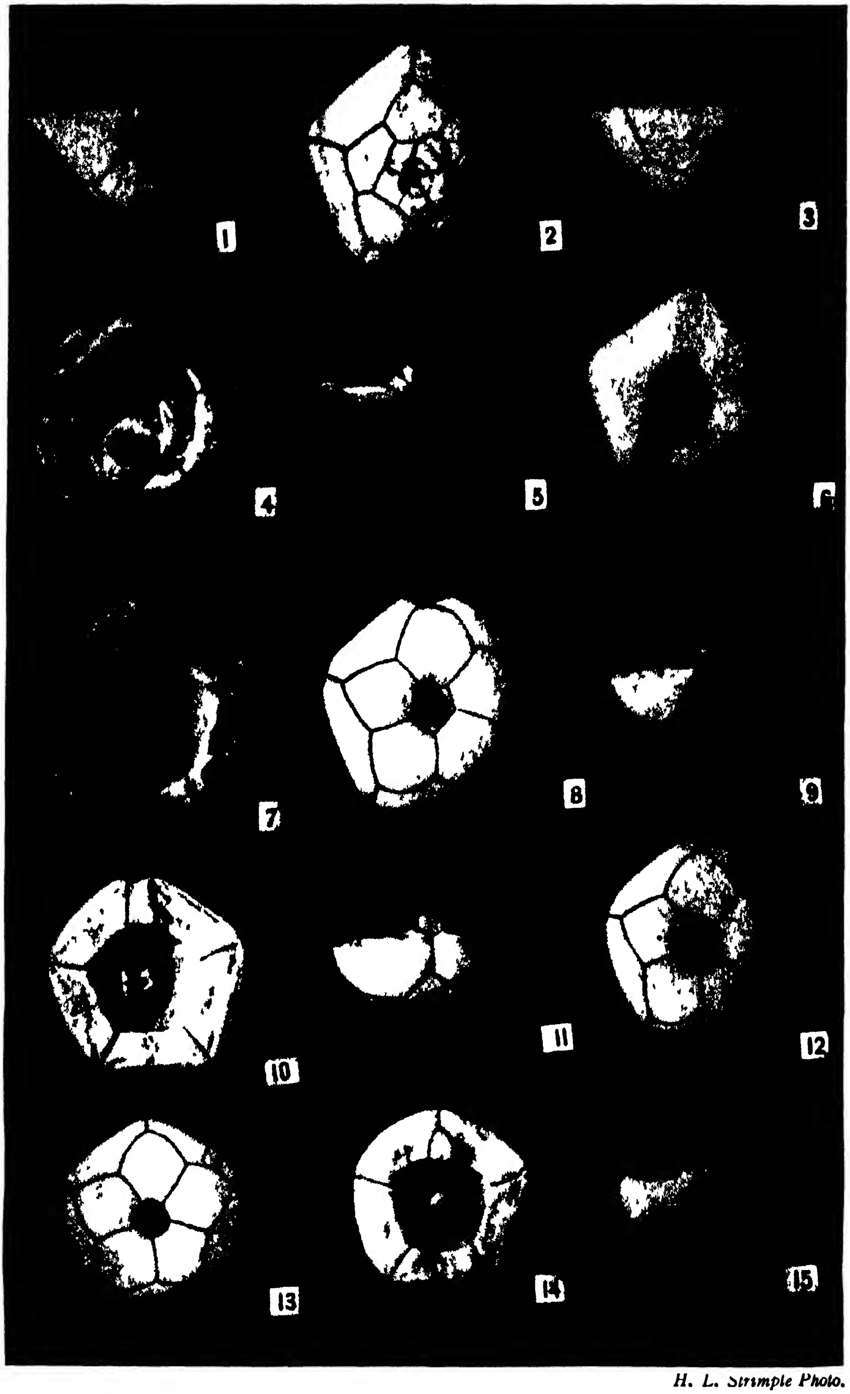

H. L. Strimple Photo.

DELOCRINUS, PARADELOCRINUS AND *STUARTWELLERCRINUS ARGENTINEI* sp. nov.

MOORE, R. C., and PLUMMER, F. E., 1938. Upper Carboniferous crinoids from the Morrow subseries of Arkansas, Oklahoma and Texts, *Denison Univ. Bull., Journ. Sci. Labs.*, xxxii, 209–313.
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EXPLANATION OF PLATE

(All figures approx. twice natural size.)

FIGS. 1–4.—*Stuartwellercrinus argentinei* sp. nov., posterior, basal, anterior and summit views of holotype from Wyandotte limestone formation, Kansas City, Missouri.

FIGS. 5–7.—*Paradelocrinus iolaensis* sp. nov., posterior, basal, and summit views of holotype from Iola limestone formation, Iola, Kansas.

FIGS. 8–10.—*Delocrinus subhemisphericus* Moore and Plummer, basal, posterior, and summit views of a specimen demonstrating " Advanced Type ", Iola limestone formation, Iola, Kansas.

FIGS. 11–15.—*Delocrinus subhemisphericus* Moore and Plummer, specimens demonstrating " Extreme Type ". Figs. 11–12.—Posterior and basal views of large cup. Figs. 13–15.—Basal, summit, and posterior views of most advanced cup observed. Iola limestone formation, Iola, Kansas.

CORRECTION

Correction to Strimple, *Geol. Mag.*, 1948, LXXXV, 113–116, Pl. X, for *Peremistocrinus*, read *Perimestocrinus*.

CORRESPONDENCE

THE ORIGIN OF RED SANDSTONES AND CONGLOMERATES

SIR,—Mr. J. B. Scrivenor's paper on the New Red Sandstone of South Devonshire, in the *Geological Magazine* for December, 1948, was of particular interest to me because, while I have examined the rocks in question only casually, I have had many opportunities to study red beds in other regions, particularly in western United States. To this may be added years of observation of the deposits now being made in arid and semi-arid regions, both temperate and sub-tropical.

From the descriptions and photographs in Mr. Scrivenor's article, I should infer with confidence that most of his conglomeratic beds were deposited as alluvial fans. Those which are distinctly but complexly stratified suggest the work of intermittent streams—muddy, but seldom loaded to full capacity. The unstratified or obscurely stratified deposits, containing angular debris and even boulders mixed together, strongly suggest mudflows, or in some cases deposits made by transient floods fully loaded with debris. Both kinds of deposits are typical of semi-arid regions such as parts of Utah and Nevada. Alluvial fans made by floods descending short steep ravines in desert regions may leave deposits consisting almost entirely of poorly sorted angular debris. Longer streams, having an opportunity to carry fragments farther, and hence to abrade them notably, have sub-angular or even well-rounded pebbles. The typical mudflow is entirely unsorted, unstratified, and may contain boulders of large size.

The colour of these red deposits varies with the proportion of clay, sand, and gravel. As the red iron oxide exists in a very fine state of division, the deposits containing little but clay are generally of a dark red or even chocolate colour, while those with but little clay may be only pink or tawny.

While there is good evidence that some red beds have been deposited in lakes, such an environment is generally unfavourable, unless the lakes are shallow and intermittent. In permanent lakes of any considerable depth, the bottom waters are ordinarily in a reducing condition, owing to the presence of decaying organic matter. Such deposits are normally some shade of grey or black, even where the inflowing streams bring in brown or red mud. This does not rule out the probability of deposition of red mud in small temporary shallow lakes incidental to the building of a river flood plain.

A dilemma is posed by the fact that red soils, which are probably the source of most red continental deposits, are characteristic of well-drained hilly regions, subject to a hot climate with generous rainfall, and the further fact that red beds commonly bear evidence of having been deposited under semi-arid or even arid conditions. Both requirements may be satisfied in regions where streams rising in a moist tropical region flow out into an arid plain, as along the north-west side of the Deccan Plateau, in India. Any other combination of conditions that would permit red soils to be produced by chemical weathering and yet would protect them from chemical reduction after transport and deposition would also meet the requirements of the case.

Mr. Scrivenor is troubled by the dimensions that seem to be required for the supposed alluvial fans in the case of the New Red Sandstone. It may be pointed out that in western United States and other regions alluvial fans of more than ten miles radius are rather common, and much larger ones are known. The very large fans generally have gradients of less than one degree, whereas small torrential fans of less than one mile radius may range from four to six degrees or, in the case of mudflow fans, as high as fifteen degrees.

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AN OCCURRENCE OF AUTHIGENIC FELSPAR AND QUARTZ IN YOREDALE LIMESTONES

SIR,—The insoluble residues from the Simonstone, and Middle Limestones of Darnbrook Fell, and from the same limestones on the ridge between Littondale and Wharfedale contain authigenic quartz and felspar crystals.

The authigenic quartz calls for little comment. The crystals range in size from ·03 × ·01 to ·27 × ·05 mm., and are prismatic in habit with pyramidal terminations. They contain abundant inclusions which are highly birefringent.

The felspars range in size from ·05 × ·025 mm. to ·175 × ·06 mm. The crystals are triclinic and elongated along the *a* axis. The faces commonly present are (001), (010), (101), (1$\bar{1}$0), but the last of these may not be developed. Usually the crystals come to rest on (001) and show clean sharp outlines. When turned on to (010), however, the (101) faces are seen to be irregular and the junctions between these and the (001) faces are not sharp. In extreme cases these junctions are so rounded that the crystal is barrel-shaped. Since the other faces are clean and have sharp junctions, these irregular features are hardly likely to be due to fracture or erosion, and it is assumed that they are original characteristics.

Average measurements for some of the interfacial angles are :—

(110) : (1$\bar{1}$0) 56° (32 measurements)
(001) : (101) 43° (10 measurements)

Other angles (not averages) are :—

(001) : (110) 72°
(101) : (110) 64°

On (001), the extinction angles measured from the edge of the pinacoid range from 1°–6°. All (001) sections show twinning and the two sets may both extinguish in + direction. These sections are length fast (elongation along the a axis) and give refractive indices of 1·529 and 1·537 (± ·001). The variation in thickness due to the presence of the (101) faces produces a gradation in the interference colour from light grey at the apices to yellow or orange at the centre.

(010) sections show no twinning and give extinction angles of about 15° measured from the edge of the pinacoid. The extinction angles may be positive or negative. Extinction is sometimes undulose. The refractive indices on this section are 1·529 and 1·531 (± ·001). The section is length fast (elongation along the a axis).

Approximate values for the refractive index are therefore $\alpha = 1·529$; $\gamma = 1·537$; birefringence = ·008. These values and the optical characters in general, approximate to Albite.

Twinning of an unusual character is seen on all (001) faces. It consists of twins on the Carlsbad law combined with wedge-shaped Albite lamellae, together with rotation twinning about the a axis. Considerable variety is to be found—ranging from almost simple Carlsbad to almost pure Albite in character, but the second rotational element is always present. Occasionally, re-entrant angles may be seen on the crystal faces.

Inclusions are invariably present and consist of granular black material, partly concentrated near the centre of the crystal and partly disseminated throughout it.

So far as the writer is aware, the only previously recorded examples of authigenic felspars in Britain are those described by D. L. Reynolds,[1] and there are no previous records of the occurrence in Britain of authigenic quartz and felspar together.

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NOTTINGHAM.
30th January, 1949.

[1] Reynolds, D. L., 1929. Some new occurrences of authigenic Potash Felspar. *Geol. Mag.*, lx, p. 390.

THE TERM "MAGMA-TYPE"

SIR,—Like Professor A. Holmes (*Geol. Mag.*, 1949, p. 71) I am grateful to Mr. M. K. and Dr. A. K. Wells (*Geol. Mag.*, 1948, p. 349) for the opportunity offered to me of expressing my opinion about names applicable to the two prevalent basalt types of the British Tertiary province. In my work bearing on this province, I have not only ceased to employ the term "magma-type" but have also abandoned the attempt to include in one type rocks belonging to the plutonic and volcanic associations. For the latter I have used the name "lava-type" (*Bull. Volcan.*, 1940, Sci. ii, vol. vi, p. 113). In this particular work, I have employed Kennedy's terms—olivine-basalt and tholeiitic basalt, but I have since come to the conclusion that these terms are not only unsatisfactory, but can be highly misleading. Although the difference between these two lava types is very striking, the difference is not expressed by the names olivine-basalt and tholeiitic basalt, for olivine is sometimes present in basalts of the so-called tholeiitic type, and several tholeiite types, such as Largs, Salen, and Corrie types belong to the, so-called, olivine-basalt type. Instead of the above-mentioned names in dealing with the two prevalent lava-types of the British Tertiary province, I prefer to use the following terms :—

1. Hebridean Type (being the prevalent lava type in the Hebrides) to replace Plateau Magma-Type (*Mull Memoir*) and Olivine-Basalt Magma-Type (Kennedy).
2. Causeway Type (as occurring in the Giant's Causeway district) to replace Non-Porphyritic Magma-Type (*Mull Memoir*). Tholeiitic Magma-Type (Kennedy).

These two lava-types are extremely contrasted rock types, but the difference between them is not expressed by the prefixes olivine- or tholeiitic, but by the general chemical and mineralogical set up. For example, the Hebridean Type is characterized by plagioclase (labradorite) being more abundant than pyroxene, while the Causeway Type is characterized by plagioclase (andesine) being less abundant than pyroxene.

These two types exhibit minor variations mainly in respect of alkalies and silica, and can be subdivided into the following sub-types : Crinanite and Plagiophyric sub-types of Hebridean Type (Plagiophyric is to replace Porphyritic Central Magma-Type of *Mull Memoir*) and Trachydolerite (Mugearite) and Staffa sub-types of Causeway Type.

This scheme does away completely with the attempt to apply mineral or textural terms to the lava-types of the British Tertiary province, and thus localizes these types and prevents their being confused with rock-types belonging to other localities or periods. To take examples, the Tertiary olivine-basalts are by no means identical with the Carboniferous olivine-basalts, and the Tertiary tholeiite basalt differs in detail from the Carboniferous quartz-dolerites. Regional names may help to clear up this confusion and restrict the lava-types to their respective localities. The more we think of age and area in regional petrology the better and clearer are our descriptions and comparisons. This is why I would like to protest not only against the use of names for so-called magma types, but also against the use of names for rock-types based on characters related to these of rock-types from other areas.

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28th March, 1949.

REVIEWS

PROCEDURE IN TAXONOMY. By E. T. SCHENCK and J. H. MCMASTERS ; 2nd edition, revised by Myra Keen and S. W. Muller. pp. vii + 93. Stanford University Press (Oxford University Press), 1948. Price $2.50.

Students of palaeozoology will welcome the reappearance of Schenck and McMasters' *Procedure in Taxonomy*, with its introductory chapters and its reprint of the English version (Biological Society, Washington) of the International Rules of Zoological Nomenclature. The second edition is enlarged, rearranged, and in part rewritten, and the summaries of Opinions Rendered are brought up to No. 194, February, 1947.

THE IMPORTANCE OF UPWELLING WATER TO VERTEBRATE PALEONTOLOGY AND OIL GEOLOGY. By M. BRONGERSMA-SANDERS. Verh. K. Nederlandsche Akad. Wetenschappen, afd. Natuurkunde ; Tweede Sect., xlv, No. 4, 1948.

The gist of the argument developed in this thesis is that the upwelling of water rendered lethal by concentration of dinoflagellates is a cause of mass mortality among fishes, etc. It is documented in respect of recent occurrences and plausible in the suggestion that such things have happened in the past. Certain peculiarities in the sediment from the azoic zone of Walvis Bay recall features of bituminous fish shales, and the author hints at a novel explanation of the common association of petroleum with salt.

O. M. B. B.

KLOCKMANN'S LEHRBUCH DER MINERALOGIE, 13th edition, revised by P. RAMDOHR. Stuttgart (F. Enke Verlag), 1948, xii + 674, 606 text-figures, 47.80 DM. (unbound), 50 DM. (bound).

This new edition of Klockmann's well known textbook of mineralogy, as revised by Professor P. Ramdohr, is a very welcome addition to the standard texts on mineralogy at present available. The work is divided into two roughly equal portions, Part I dealing with general mineralogy and including sections on crystallography, optical and other physical properties, crystal structure and crystal chemistry, occurrence and paragenesis, economic uses of minerals, and a valuable section on famous mineral localities. Part II gives a systematic description of most known minerals (including lattice constants and structure type where these have been determined), and there are excellent detailed indices.

Two minor criticisms may be offered. The symbol XX for crystals is perhaps allowable in the descriptive portion of the text but should not be used throughout Part I, and far too many different symbols are used for refractive indices instead of adopting one standard set.

S. R. N.

MINERALS AND MINERAL DEPOSITS. By W. R. JONES and DAVID WILLIAMS (No. 202 of The Home University Library of Modern Knowledge). Oxford University Press, 1948, vii + 248, 56 text-figures. 5*s*.

This little book aims at interesting the layman in various aspects of the subject of minerals and in this it should succeed, as the subject-matter is clearly and attractively presented. After considering the composition of the earth's crust, the shapes of minerals and their internal structure and physical characters, the common rock types, and economic mineral deposits, the authors deal with the distribution of the chief metalliferous minerals, the search for mineral deposits (which includes an account of geophysical methods of prospecting), the extraction of minerals and metals, minerals in the industrial age, and some international aspects of mineral resources. There is a glossary of minerals and rocks mentioned in the text. The chapter on internal

structure of minerals calls for particular comment as here may be found some account of types of bonding and the importance of ionic size and charge in the formation of minerals, topics still neglected all too often in books on minerals.

Although primarily intended for the general reader, the book will be of value to all students of geology who wish to know something about mineral deposits and their importance in the modern world.

S. R. N.

SEQUENCE IN LAYERED ROCKS. By R. R. SHROCK. pp. xiii + 507, with 397 text-figs. New York, Toronto, London: McGraw-Hill, 1948. Price 45*s*.

There are immense areas where, overwhelmingly, dips and faults are normal. Within them an observer, such as William Smith, can assume with little risk of error that he knows the relative age of two neighbour formations as soon as he has established the direction of inclination of their contact. There are other extensive areas where dips, though often exceeding 90°, seldom reach 180° (true). In them, dips, which follow the direction of fold-pitch, can still as a rule be used to settle age problems without further qualification; but the more numerous limb-dips can only be employed if associated cleavage or drag-folding allows us to discriminate between normal and reversed fold-limbs. Last of all there are particularly disturbed areas, where dips quite commonly surpass 180° (true). Here the stratigrapher must abandon dip altogether as a criterion of age, and look elsewhere for assistance. He may find it in fossil succession, or in some clearly marked major unconformity; or alternatively in one or other of a great variety of intimate indications of original up-or-down, which have proved of increasing importance in comparatively recent research. Perusal of Shrock's extremely interesting and helpfully illustrated book leaves the impression that the most widespread criteria are supplied by: current and graded bedding in detrital deposits; stromatalites (probably algal) in limestones; and pipe amygdales and accommodation deformation of pillows in lavas.

Shrock's review of British and American literature is fuller than any previously attempted. He lists 737 publications grouping them according to author and subject; but unfortunately omits page references to his own text, such as one is accustomed to find in an author-index.

Let us begin by noting a few historical items. J. Kelly, in Ireland, was using current bedding to distinguish normal and reversed dips as early as 1864 (p. 251)—though modern practice only seems to have started with (? W. M.) Davis sometime before 1910 (p. 251). J. B. Jukes and A. Geikie noted the top and bottom difference of symmetrical ripple marks in 1872 (p. 113). I myself am credited, somewhat to my surprise, with the first recorded recognition of the up-or-down value of graded bedding in 1906 (p. 82); but, as is well known, I did not appreciate the possible wide application of this criterion until educated in 1927 by Canadian and American geologists—and these dated their training back to C. K. Leith, of Wisconsin University, let us say from 1913 (p. 82). J. Barrell employed algal structures in 1913 (p. 287). B. N. Peach was perhaps the first to use pipe amygdales as an up-or-down criterion (p. 353—Peach published in 1911; J. Nicol was much earlier in a successful employment of pipes to demonstrate inversion—but Shrock, quoting, p. 352, from a quotation, has not realized that Nicol's pipes were "worm"-tubes, not amygdales). M. E. Wilson since 1911 has been elucidating lava successions, an extremely important matter in the Canadian Precambrian, by pillow forms (p. 364). The use of dip and unconformity in simple country is, of course, as old as geology. The availability of pitch as a guide to age relations in regions of intermediate complexity depends largely upon R. Pumpelly's rule that "the degree and direction of the pitch of a fold are often indicated by those of the axes of the minor

plications on its sides", published in 1894 (p. 432). "Van Hise, Leith, Mead, and others of the Wisconsin group" seem to have been mainly responsible for fruitful combination of stratal dip with cleavage and drag-fold phenomena, "although the principles they applied and refined . . . had been developed many years before by Heim (1878), Loretz (1882), and others" (p. 446). Shrock's comments, combined with, for instance, those of G. Wilson in the *Proc. Geol. Assoc.*, 1947, give us a fair idea of the growth of knowledge in this matter; but it would be very welcome some day to have an ordered critical account from the main protagonist, C. K. Leith.

Stratified partial infillings of cavities, such as shell interiors in sediments and vesicles in lavas, have as yet only provided minor assistance in unravelling folds; but they are very attractive, and Shrock has given them special attention (pp. 2, 4, 281–4, 306, 320–6, 350–1, 376–383). His main references are to A. Hadding, 1929, and J. S. Cullison, 1937, 1938, for sediments, and J. D. Dana, 1845, and W. M. Davis, 1880, for lavas. I am certain Shrock will welcome a recently recorded analogue (*Q.J.G.S.* for 1944, p. 17) to what he calls F. K. Morris' "bathtub rings" (p. 377). "Differentially eroded fossils" as criteria of up-or-down are covered by a single example (p. 319). To this one may usefully add G. W. Lamplugh's apt refutation of a famous inversion hypothesis applied by F. L. Kitchin to a particular exposure of Gault Clay (*Q.J.G.S.*, 1922, p. 9).

Shrock's book may be likened to a reservoir with an extraordinarily wide catchment area and destined to irrigate a very varied and as yet only partially developed field of research. It is particularly pleasant to find references to 18 papers by E. M. Kindle, whose observations and experiments always repay careful study; also to many writings of Kindle's colleagues on the Canadian Geological Survey, who like the Wisconsin School across the border were well ahead of us in Scotland in utilizing various up-or-down criteria. Some few of Shrock's entries should encourage healthy criticism, but most of them are obviously well founded, and many are provocative of further speculation. For instance, Wilson's discovery that the upper pillows of a pillow lava are generally moulded on the lower (p. 365) suggests that pillows have usually been added from above and have rolled down into place. If so a pillowy lava-top must usually be distributed by carry on an underlying molten stream, which, of course, by peripheral escape may be establishing new sources of pillows. Again, Shrock suggests that study of gas-plus-solid inclusions in the porphyritic quartzes of rhyolites may afford valuable indications of the relative orientation of crystal to gravity at the time of growth (p. 375). This certainly encourages a novel approach to the perennial magma-migma controversy that centres on granite. Anyone taking up the matter should first study L. Hawkes on glomero-granular texture (*Min. Mag.*, 1929, p. 168).

Shrock constantly points to need for caution in applying any particular up-or-down test. Consider a *Productus*. During life it lay convex downwards, so as to be able to open. After death, if agitated by waves it tended to wobble over into the position of most stable equilibrium. This, as Sorby pointed out in 1908, is convex upwards (p. 316).

Readers will probably realize by now that Shrock does not intend his book to be a mere guide to recognition of inversion. This idea does indeed supply a background, but it is often almost lost sight of behind a rich growth of natural history. Much interesting material, for instance, has been gathered to illustrate cyclic or rhythmic sedimentation (pp. 27–40). The earliest of a series of references is to J. A. Udden, 1912 (p. 34). Of course, the phenomenon had attracted attention long before the start of the present century. Thus, B. N. Peach, in a presidential address to the Royal Physical Society of Edinburgh in 1885, was able to say that "when the succession", representing a cycle within the Carboniferous Limestone Series of Scotland "is complete the following is the arrangement of the strata in ascending order: (1) limestone charged with ordinary marine fossils; (2) shales yielding stunted marine forms; (3) sandstone; (4) fireclay with the roots

of plants which is overlain by a coal seam. . . . The bed of limestone which frequently forms the roof of a coal seam represents another depression of the land surface, and the return of marine organisms forming the first stage in the same [next similar] cycle of physical conditions. . . . The same cycle of physical conditions must have been repeated again and again" (*Proc. Roy. Phys. Soc.*, vol. ix, p. 17; see also vice-president's address, 1914, vol. xix, p. 251). I had written this much when, on opening T. Robertson's "Rhythm in Sedimentation", in the 1948 *Trans. Edin. Geol. Soc.*, I found a very apposite reference to J. W. Dawson (*Q.J.G.S.*, 1854, p. 15), in which appears: "It is remarkable that in almost every instance" in the Coal Measures of Nova Scotia "the conditions for the formation of these limestones and their allied *Modiola*-shales have followed immediately on the formation of layers of coal based on underclays".

Of the finding of records there is no end. Let us therefore congratulate Shrock on not unduly delaying the appearance of his book in the vain endeavour to reach completeness. At the same time we can share his half expressed hope that some one whose home tongue is not English may before long produce a parallel contribution. Meanwhile, let us conclude this notice with a word or two in relation to over-condensation of terminology.

I confess I read with something of a shock a paragraph entitled "Chilled Top and Bottom Margins", which starts: "Ancient flows, as well as those of recent formation, have a chilled zone along both upper and lower margins. The upper zone is usually much thicker than the lower" (pp. 348, 401). It so happens that chilled-margin phraseology grew up a very long time ago among Scottish geologists who, *in the sense in which they use the terms*, find that lavas can be distinguished from minor intrusions by *never* showing chilled tops and *very seldom* chilled bases, except in the case of pillow lavas (this nowadays is their main reason for interpreting lava pillows as, if one cares to use the phrase, intrusions into water). The apparent contradiction of Scottish and Canada-American statement in the matter is, I think, due in part to laxity in our Scottish wording. "Chilled margin" for us has always meant "compact chilled margin". We have never spoken of a covering of glassy froth or a layer of pillows as a chilled top. We shall in future, I hope, aim at being more explicit. However, the laxity is not altogether on our side. It scarcely seems right for Shrock to speak of a chilled *margin* or *top*, for there appears to be usually a very gradual increase of grain size from the top of a flow to within "a few inches of the bottom" (cf. H. C. Cooke, W. F. James, and J. B. Mawdsley, 1931).

Finally, I may offer a warning against accepting too readily Shrock's verb "to face", in the sense in which Canadians use "to top" and I myself "to young". The difficulty of remembering that "to face" means "to present what was originally the top face" (p. 17) is illustrated by the fact that on p. 34 Shrock becomes self-contradictory in the matter. "To top" is less likely to be misunderstood than "to face", for it involves only one unexpressed idea, namely originality. On the whole I prefer "to young", because, though barbarous, it is self-sufficient.

E. B. BAILEY.

THE PALAEOGEOGRAPHY OF THE MIDLANDS. By PROFESSOR L. J. WILLS. pp. 144, 38 figures, and 5 plates. University Press of Liverpool, 1948. Price 10*s*. 6*d*.

This volume is written in the same concise and reflective style which characterizes the author's earlier and larger book on the physiographical evolution of the whole of Britain. Evidence and inference are skilfully combined in continuous narrative. Professor Wills calls wherever necessary upon evidence beyond the boundaries of the Midlands, and among the illustrations are twelve palaeogeographical maps covering the whole area of the British Isles and two covering western Europe.

The succession of post-Archaean events is grouped and discussed as an

alternating series of six continental phases and five marine phases, beginning with terrestrial denudation of the Pre-Cambrian surface and the marine Cambrian transgression. In his account of Ordovician geography the author favours the idea of a southern sea, with fauna of Grés de May type, extending into Central England to provide a local source for the Ordovician quartzite pebbles of the Midland Bunter. A map of Upper Salopian geography, taking account of the cores of Denbighshire Salopian type drawn long ago from borings near Harwich, shows shallow Midland waters flanked by a geosynclinal sea to the north-east as well as to the north-west. In a discussion of the facies and correlation of the Downtonian and Dittonian, the author concludes that both series should be retained as Silurian. Our lack of precise knowledge concerning the palaeogeography of the Dinantian transgression is stressed. The account of Namurian and Westphalian conditions includes comparative illustrations of rhythmic sedimentation in the Dudley and Cannock areas, and an interesting diagram of the pre-Halesowen unconformity.

The section devoted to the New Red Sandstone, in which all deposits from Keele Beds to Keuper are grouped, contains a great deal that is new. The relations and ages of many of these red rocks, and particularly of the host of local breccias and conglomerates, have long been a cause of argument. Professor Wills proposes a satisfying palaeogeographical synthesis, a modified nomenclature and a correlation which may not be inconsistent with Sherlock's views on the British Permo-Triassic rocks. The Enville and Clent Breccia Groups are equated with the Rotliegende. The Lower Mottled Sandstone is renamed the Bridgnorth or Dune Sandstone Group ; and it is suggested, following work by F. W. Shotton, that this group may be correlated with the Penrith Sandstone, and thus be of Zechstein age. The term Moulding Sand Group is proposed for the Upper Mottled Sandstone ; and Bromsgrove Group as an alternative for the Lower Keuper Sandstone.

After a well-illustrated chapter on late Mesozoic and Palaeogene times, the author discusses the development of pre-Pleistocene drainage systems, with particular attention to the effects of mid-Tertiary uplift of the now-visible coalfields. Finally, there are two chapters on the Older and Newer Drifts which, for the sake of brevity are written as a consecutive, historical account, without full quotation of evidence. Although the author expresses diffidence about their style, they will stand as a valuable key to the complicated literature on the Midland Pleistocene. The whole book will be a stimulus and a source of pleasure to any geologist who is interested in the evolutionary interpretation of stratigraphy.

A. J. B.

USEFUL ASPECTS OF GEOLOGY. By S. J. SHAND. 3rd edition, pp. 182, with 30 text-figures. London : Murby (Allen and Unwin). 1947. Price 10*s*. 6*d*.

We welcome the third edition of this most useful little book. The original work owed much of its inspiration to the author's experiences in South Africa, a country where even twenty-five years ago geology was taken seriously, and not regarded as the hobby of a few cranks. In that land there are few fossils to complicate the subject, and the stress is mainly on structure and mineralogy.

Here we have an enormous amount of useful information clearly expressed in a much condensed form, often in sentences almost epigrammatic in their terseness and point. The book can be strongly recommended to the growing number of people who realize the importance of geology in underground exploration, especially as regards oil-finding and water-supply, two subjects of special current importance in this country at present.

R. H. R.

GEOLOGY. By H. H. READ. pp. 248 with 30 figures. Home University Library. Oxford University Press. 1949. Price 5*s*.

This is a peculiarly difficult book to review, since so much depends on the standpoint of the reviewer—whether, to put it shortly, it is to be taken as wildly unorthodox, or as completely up to date. The author's own opinions, as set forth in several recent Presidential Addresses, are well-known, and they are all here. It remains to be seen whether they are to become orthodoxy.

The book consists of five chapters, of which the first is mainly historical, beginning with da Vinci, then Lehmann and Füchsel in Thuringia, who were almost forgotten later; Desmarest; Werner and his followers; Hutton and William Smith. Lyell may perhaps be now regarded as the first really modern geologist, although he was at first regarded as a heretic.

The second chapter contains a discussion of the origin of sediments, with special emphasis on facies—and a preliminary account of isostasy and the problem of the permanence or otherwise of continents and oceans and the question of continental drift, which are discussed more fully in the next chapter. This is followed by a section on classification and nomenclature of systems. The names accepted for the larger divisions are Palaeozoic, Mesozoic, and Tertiary, the inconsistency being excused on the ground that nobody can spell the *zoic* form for the Tertiary.

It may be noted here as specially interesting that the method of age-determination by lead-helium ratios seems to have been swallowed by Authority without any fuss, such as usually accompanies novelties of the first rank.

The next chapter is the most exciting in the book, for it is here that we come up against the author's own particular *doxy*, namely the granite problem and the classification of the igneous and metamorphic rocks. It is emphasized that no one has ever seen a granite magma consolidating, as basalt can be seen any day in a volcano. The formation of all granitic rocks, however it is done, takes place in depth. It is impossible to discuss the whole subject here. It must suffice to say that the author returns to what is practically Lyell's classification, with the important addition of the theory of migmatites—but there seems to be no mention of basic fronts. There can be little doubt that some form of granitization is now accepted by everybody for at any rate the larger masses, although some smaller masses, especially dykes and veins are probably formed by direct solidification of granite magma. It may be noted that in discussions of the role of granite magma it is never made clear where it is supposed to come from. However, granite batholiths may now be regarded as the extreme form of migmatite—the *room problem* makes any other solution impossible.

The author's final classification of rocks, then, may be summarized as: Neptunic (= Sediments); Volcanic; and Plutonic (= granitic + metamorphic), metamorphism being here considered as comprising what is commonly called regional, i.e. the metamorphism of the shields, ordinary thermal or contact and dynamic being excluded.

In his discussion of continental drift, which is dealt with largely in opposition to transoceanic land-bridges, the general impression left is that the author believes that it happened, from purely geological evidence, although no efficient cause has yet been found, but this is by no means the only instance of such a state of affairs in geology.

The fifth and longest chapter consists of a discussion of world-history, mainly from the tectonic point of view. This chapter is of extraordinary interest and remarkably good. Only one definite error has been noticed concerning the transition from Jurassic to Cretaceous in Britain "in Yorkshire marine conditions continued into Cretaceous times". In fact, in Yorkshire there is here a long gap in the succession, Portland, Purbeck, and lowest Cretaceous being absent.

Altogether, this is a fascinating little book, only 239 very small pages of text, and should do much to spread the knowledge of the latest developments of geology—though it may be a bit of a shock to some people.

R. H. R.

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Shore Platforms

By E. SHERBON HILLS

(PLATES V–VII)

ABSTRACT

The use of the terms " normal " and " abnormal " in relation to shore-platforms has led to confusion and should be discontinued. Processes operative in the formation of shore platforms are analysed from Victorian examples. The effects of water-layer weathering, growth of marine organisms, breakers, and waves of translation on sheltered and open coasts and on various rocks (including a special study of platforms in aeolianites) are discussed.

INTRODUCTION

SHORE platforms are notable features of most rocky coasts, but few and scant references to them are to be found in the early physiographic literature, including the classic works of Fenneman (1902) and Douglas Johnson (1919) on shore processes. Briefly, the major problem presented by platforms about or above mean sea-level is why they should form at all, when it is obvious from the fact that they may be deeply channelled and pot-holed, that the sea is well capable of strong erosion below their level. It is now recognized that many shore platforms do not conform to the profile of equilibrium propounded by Fenneman and Johnson, and that factors other than those involved in the formation of the profile of equilibrium must operate to produce such platforms. Interest in the subject has been stimulated in Australia and the Pacific region because of the inferences that have been drawn from the existence of platforms above the level of the profile of equilibrium, as to recent emergence of the land relative to sea-level, and references to this aspect of the subject will be found in the works of Bartrum, Wentworth, Jutson, and Johnson, listed below.

TYPES OF SHORE PLATFORMS

In the classic discussions of the British school on the potency of marine erosion to produce plains of denudation, various levels were given for the depth at which marine planation occurs, and the attitude of shore platforms in relation to the submarine plain of denudation was not, so far as I can discover, clearly defined. Geikie's statement

that the ultimate level of marine sculpturing is the lower limit of wave action (1885) does, however, imply that shore platforms about mean sea-level must be higher than this. Kinahan (*fide* de Lapparent, 1906) recorded the existence at Inishmore of a series of shore platforms at elevations both above and below mean sea-level, which he explained as being the result of wave action at high equinoctial tides, high ordinary tides, low ordinary tides, and low equinoctial tides respectively. This explanation appears to have in it the germ of ideas expressed by later writers as to the formation of platforms at various levels as a result of normal physiographic processes. De Lapparent (1906) has illustrated a feature that is also stressed by later workers—that the seaward edge of a shore platform is usually marked by a " low tide cliff ". Fenneman (1902) and Johnson (1919) do not refer to details such as these in connection with the concept of the " normal profile " or " profile of equilibrium ". Johnson's well-known diagrams show clearly that in this hypothetical profile the platform exposed between high and low water levels at the stage of maturity is part of a smooth profile extending out from the base of the cliffs first as the " cut terrace " and beyond this as the " built terrace ", at the depth to which wave action has been effective up to the time considered. Shore platforms are represented in younger stages of erosion as transient features only, undergoing progressive reduction in level as erosion approaches maturity.

In 1916, however, Bartrum had already described rock platforms in New Zealand (including the " Old Hat " referred to by Dana (1880) as disturbing the " normal shore profile " of Fenneman, and later (1926, 1935) he specifically designated this and certain other types of shore platforms as " abnormal ", but made the reservation (1935) that he " continues to believe, nevertheless, that they are in truth by no means abnormal, but must be regarded as an expectable consequence of shore-line erosion wherever local conditions comply with certain requirements " (see also Bartrum, 1926, p. 793).

According to Bartrum, platforms of the Old Hat type result from the progressive destruction of the cliff face by subaerial erosion down to the level of permanent saturation (a little below mean high-water level), while weak waves remove the products of disintegration. The seaward edge of the platform is marked by a drop of a few feet to a surface which is regarded as part of the normal shore profile carved from more resistant unweathered rocks below high-water level.

The second type of shore platform classed as " abnormal " by Bartrum is termed by him " storm-wave platforms " (1924, 1926). These are described as being narrow benches often developed at a height of a few feet above high-water level, as a result of the action of storm waves. There is an abrupt descent at their seaward edge into water which is several feet deep at low tide, due to the waves attempting

to " reproduce the normal shore profile under normal conditions or at lower stages of the tide ".

Subsequently, incorporating the results of further observations, Bartrum (1935) has listed the characteristics of storm-wave platforms as follows :—

(*a*) Surface—from about normal high-water level to a few feet above this.

(*b*) Found only where wave attack is vigorous.

(*c*) Cliffs commonly overhang the platforms, showing no sign of weathering. Cliffs attacked during storms.

(*d*) Bench frequently truncates inclined strata.

(*e*) Surface generally moderately irregular near seaward end of headlands, but baywards tends to become almost a plane, because of modification of the wave-cut bench by a subsequent different process.

(*f*) Sea generally shallow—oncoming waves break before reaching the platform.

(*g*) Vigorous kelp is generally attached to steep outer slope and appears to assist in its preservation.

(*h*) Surfaces are typically free from debris except for recent rock-falls.

(*i*) Perhaps a considerable tidal range is a helpful genetic factor.

Bartrum also suggests the hypothesis in this paper that storm-wave platforms may be reduced by secondary subaerial planation to remarkably plane surfaces, in some places above normal high-water level, elsewhere below this, so that by a continuation of storm-wave attack weathering, and removal of weathered rock by waves both weak and strong, platforms with various degrees of perfection as planes may be formed from some feet above high-water mark to a level between between high and low-water.

Were it not that Jutson has consistently applied the term " normal " to shore platforms having the characteristics of some of those described by Bartrum—that is developing between low- and high-water level and having a steep drop of a few feet at the off-shore edge—there would be little need to consider the applicability of the terms " normal " and " abnormal " in connection with shore platforms, since Bartrum gives more specific terms for the " abnormal " platforms and this latter term could conveniently be dropped.

Jutson (1940) recognizes the following platforms along the shores described by him, from above downwards :—

(*a*) " High-level " platforms—average height about 3 feet above the normal platforms, but not constant. Many portions of this platform are awash at mean high tide, other parts are covered only by exceptionally high seas.

(*b*) The " Normal platform "—exposed between mean low tide and mean high tide.

(*c*) The " Ultimate platform "—well below low water level. This is regarded as part of the " normal profile " of Fenneman, and Jutson recognizes that it may in time be further reduced by erosion, or covered with detritus.

If a normal platform is not developed at all then the ultimate platform is developed as a primary feature and is termed the primary ultimate platform ; where the normal platform is present, the ultimate platform is developed as a result of encroachment on the outer edge of the normal platform, and is then termed the " secondary ultimate platform ".

Edwards (1941 a, b ; 1942, 1945) has described shore platforms along the coast of Victoria and Tasmania as storm-wave platforms in Bartrum's sense, rejecting Jutson's terms as unsuitable. On the other hand, Wentworth (1938, 1939) does not appear to subscribe to Bartrum's conception of the development of sub-horizontal platforms above high-water level by wave action alone, and the present writer does not accept as storm-wave platforms several of the features so described by Edwards, as will be explained below.

To be acceptable, a physiographic term should relate to a clearly defined set of conditions and processes, so that the genesis of a feature designated by the term shall be understood. Jutson's terms are, however, largely descriptive and therefore highly subjective. While the writer would agree that a platform about mean sea-level is most commonly developed along coasts, such platforms are, he believes, not always formed in the same way. Furthermore, as Jutson admits, such platforms are not everywhere developed, although the conditions of rocks and waves may not be abnormal where they are absent. Again, this is not the only level at which platforms may develop by normal physiographic processes. For these reasons it is not proposed to use the term " normal platform " ; it is also suggested that the term, " abnormal platform ", if used at all, had best be applied to such as cannot be explained by processes acting at the place under consideration during the present time. An abnormal platform might be a raised platform, or one formed under conditions of tide, of wind, or of some other factor, differing from those now obtaining. The term " ultimate platform " is almost synonymous with Fenneman's " normal profile of equilibrium ", except that the latter is more properly applicable to a cross-section of a coast, and its use introduces a further complexity with regard to the word " normal ". For this reason, and because the ultimate platform is in fact subject to further reduction in level by prolonged erosion and is therefore not the ultimate level of marine planation, use of the term is not favoured.

It is hoped that a nomenclature based on genetic conceptions, as partially outlined by Wentworth (1938, 1939), may eventually be arrived at.

Processes in Platform-Development

Before considering the general question of wave attack on a rocky shore, the effects of other processes should first be dealt with, so that such effects may be recognized and excluded from the analysis of wave action.

Water-level weathering.

This process was first described by Bartrum and Turner (1928) and later by Bartrum (1935). It was subsequently named and more completely analysed by Wentworth (1938, 1939). Weathering of rock exposed above the level of water standing in very shallow pools results in well-nigh plane, level surfaces, formed at various elevations between low- and high-water level, and even several feet above high-water level in places where splash and spray can lodge. The location of pools is primarily determined by some other agent, either wave action or subaerial erosion. Johnson (1938) has raised objections to the term because of possible confusion with sea-level. Wentworth's term refers to the various levels in different shallow pools or puddles, which are simply layers of water, and it may therefore be preferable to use the term "water-layer weathering", instead of "water-level weathering", which latter term should, I agree, be reserved for weathering related to the general level of the sea and of ground water in the immediate vicinity of the shore, as in platforms of the Old Hat type.

The process is admirably demonstrated along the Victorian coast, but is much more important in certain rocks than in others. In the districts studied, Jurassic felspathic sandstones and shales, Tertiary basalts and basalt tuffs, and Tertiary ferruginous sandstones have been most affected. On exposed coasts splash and spray pools many feet above high-water mark develop horizontal water-layered surfaces, in places several square yards in area, which are particularly common on the exposed southern coast of the San Remo Peninsula in the Jurassic sandstones and shales (Plate V). As noted by Edwards (1942), the joints in these rocks are often hardened by deposits of limonite, and an extensive water-layer will then consist of a series of more or less isolated puddles, each developing on a joint-block, and having a rim a fraction of an inch high consisting of the limonite-indurated rock, or simply limonite. Water layers occurring well out of reach of direct wave-attack by virtue either of their elevation or of protection among the crags of the cliffs are identical, except in their smaller size, with those that are awash at high tide, and the rapid fretting by alternate wetting and drying of rock rising above the pools is readily verifiable in the field.

In slightly weathered Tertiary basalts on Phillip Island, a series of stages in water-layer weathering is observable (for example, at Smith's Beach) in which the general level of the sea is dominant because of open jointing in the rocks. The basalt is polygonally jointed, and the joint planes, being occupied by water between low- and high-water level, typically weather to an open, smooth, U-shaped section, in which the water occupies the bottom of the U, often only in the actual joint plane itself (Plate VI, fig. 1). The rock immediately adjacent to the water is repeatedly wetted by splash from ripples and dried in the air, so that it disintegrates and the troughs thus broaden. At their edges the walls are undercut for an inch or so in many instances. At the intersection of joint planes, at first small, and later large water-layered surfaces form, and because of intercommunication between the joints the level of the weathered troughs may be the same over areas of several square yards. Residuals of basalt remain between the joints, having rough surfaces that are attacked by the waves mainly by quarrying and to a lesser degree by abrasion. Places from which freshly removed joint blocks have gone are easily recognizable. It is clear from the fact that the water-layer weathered troughs are equally well developed in all the various directions that the joints take, whether protected or not by upstanding residuals of basalt, that neither swash nor plunge of waves is primarily responsible for their formation, although the channels are kept clear of detritus by the swash that travels along them. The delicate undercutting of edges at a well-defined level is, however, a clear indication that erosion by surging water is subordinate to weathering in forming the troughs.

Influence of rock type in water-layer weathering.

This process can operate only in rocks that, for one or another reason fret more rapidly under conditions of alternate wetting and drying than when permanently saturated. On Smith's Beach, for instance, a large residual of quartzite (representing silicified interbasaltic sand) rises sharply above the basaltic shore platform. The quartzite is virtually unaffected by sub-aerial weathering and therefore shows no effects due to water-layer action at all. At the same locality, too, strike ridges and other masses of " harder " basalt rise a few feet above the level of rocks that have been perfectly levelled off (Plate VI, fig. 2). Edwards (1941) and Jutson (1940) have pointed out that shore platforms are very imperfectly developed in fresh granites in southern Victoria, whereas it is known (Hills, 1940 ; Jutson, 1940) that they are well-formed in weathered granite. I take it that, to the extent that water-layer weathering may be involved on these granitic coasts, the process would be very slow in the fresh rock but would readily affect that in which the felspars were kaolinized.

Effects of marine organisms.

It is notable that on many parts of the Victorian coast growth of marine plants and animals is so profuse as to form an almost uninterrupted cover to rock surfaces below a certain level, which is usually quite sharply defined. Above this level the rocks are bare or have organisms very sparsely attached, usually in crannies or holes that retain water. The actual level concerned is usually about mean sea-level, although it may vary according to local conditions of porosity of the rocks, vigour of waves, and also with different organisms. Where a shore platform is affected by water-layer or water-level weathering, but has residuals rising above the level surfaces, it may be observed that the highest widespread levelling corresponds with the upper limit of profuse growth of organisms that presumably require perpetual moisture in the rocks in order to survive. Higher water-layered surfaces may occur, but these will usually be small and will occur only where the tightness of the rocks or the high range of splash permits the formation of local pools which form on top of the patches of tight rock. On platforms between high- and low-water level, the sea grape (*Hormosira*), mussel colonies, and other growths, may form a mat over which it is difficult to walk (see Plate VII, fig. 1). Such a mat, indicating as it must at least approximately the level of permanent saturation below which water-layer weathering cannot operate effectively, has also an important effect in protecting the platform from abrasion, for boulders moved over it by the waves may not come in contact with the rock at all where the growth is dense. Protection is also afforded from wave quarrying due to the plunge of breakers, and it is indeed obvious from the great width of platforms (in many places over 100 yards wide, and often 200 yards) that wave attack on their surfaces, once they are formed, is entirely subordinate.

A further effect of such growths is to protect the rock from drying, even on the surface skin, at low tide. Although weathering must be very slow below the level of saturation, it cannot be denied that the surface skin, and small projecting pieces of rock at the edges of crevices or holes will dry out down to low-tide level, especially on hot days. Thus, it is expectable that a platform primarily developed at mean water level would show a gradual slope up from about low-tide level to the upper limit of profuse marine growths, and such a condition is in fact found in most instances (although not with the platforms developed in dune limestone, described below). Another effect which would contribute to the formation of a gently sloping platform would be wave action on the platform (as distinct from the attack on its seaward edge). The outer parts, being older, would have suffered more prolonged attack and would therefore be lower than the landward zone.

Width and perfection of water-levelled surfaces.

In Victorian examples, shore platforms (again with the exception of those in dune limestone) are broadest and smoothest on sheltered coasts that are not subjected to waves of more than moderate force. On the open coast, which is affected by very strong on-shore gales, platforms are narrower, less regular, and have other features that are to be related to the effects of powerful waves. Platforms on the sheltered coasts, as for instance on Phillip Island between Cat Bay and Ventnor (Plate VI, fig. 3), are up to 200 yards wide, rising very gradually from about low water level to an average of about 3 feet above lower water level, and about 2 to 3 feet below high-water level.[1] On open coasts, strong attack on the seaward edges of the inter-tidal platform is obvious. Great wave-quarried blocks lie in the breakers in places, the edge of the platform is strongly eroded into numerous gulches and chasms, which may extend right through it to the cliff, and observation shows that the breakers pound the edge of the platform, armed with a visible load of pebbles and sand. This attack by swell or forced waves is virtually as effective at low-tide as at high—perhaps more so since the waves break at low-tide on the rocks themselves without an intervening water cushion. Under such conditions the " low-tide cliff " referred to by Bartrum, Jutson, and Edwards is well developed, and marks the seaward edge of the shore platform.

In sheltered waters, on the other hand, wave action is at all times weak, and the great width of the perfectly developed platforms is to be ascribed to the fact that erosion of their seaward edges is very slight. Water-layer weathering, and subaerial weathering of the cliffs, combined with the removal of detritus by the weak waves at high tide, account for the observed features. On such coasts, the total volume of eroded rock is less than on exposed coasts. The retreat of the cliffs, by means of which the platform is widened, takes place partly by subaerial weathering and partly by attack at the base by waves of translation that sweep over the shore platform, in the manner described by Bartrum for shore platforms of the Old Hat type (1926). In most of the Victorian examples, however, as one traverses from an exposed to a sheltered coast, it is seen that platforms in half-sheltered positions (as where the south-west gales are nearly parallel to the shore) are very well developed but have numerous residuals of fresh rock rising above them. It would seem, therefore, that weathering of the cliff face as described by Bartrum for the Old Hat has not been a necessary factor in such instances, although, as in Bartrum's type, it is the level of saturation that is most important in determining the shore platform.

[1] Tide gauges have not been used in this work, and the terms used relate to average tidal conditions as observed on the beaches.

In some localities too, wave attack is less important than subaerial weathering in removing the cliff. The platforms described have, therefore, many features in common with the Old Hat type, but are not precisely similar. Especially it must be noted that the Victorian platforms in sheltered waters, where they are best developed, are closer in their average elevation to mean sea-level than to mean high-water level. In many localities, too, where the rock is clearly weathered in the cliffs, the lower limit of strong weathering is well above mean high-water level. In such instances the weathered rock is stripped off the fresh, leaving a rough platform level that is not at all likely to be confused with the true marine platform. The latter, developed about mean sea-level, often has rather flat-topped residuals, the summit levels of which correspond with the depth of weathering in the cliffs, slightly reduced by subsequent denudation.

Shore Platforms in Dune Limestone

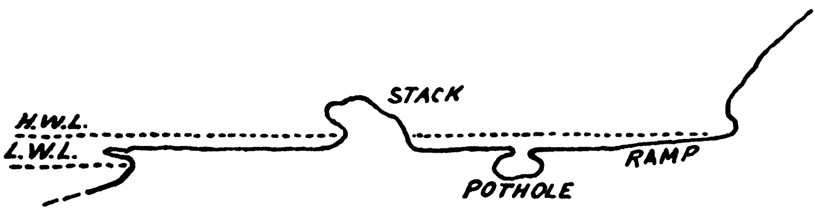
The formation of shore platforms in consolidated Pleistocene calcareous aeolianites has been studied at Point Lonsdale on the western side of the entrance to Port Phillip Bay, and at Sorrento, on the eastern side. The platforms are remarkable for their almost perfectly plane surfaces, marred only by rare residuals, potholes, and chasms, and equally for their horizontality, great breadth, and lateral extent (Plate VII, fig. 1). At Point Lonsdale the platform extends out from the cliffs in the form of a spit for almost a quarter of a mile, broken by deep channels in places and, for this part, ideas as to its formation need not be concerned with detritus supplied from the cliffs.

The platform of this spit differs in no way from those which immediately front the cliffs at Point Lonsdale and at Sorrento. They are all virtually horizontal, with differences of elevation of only a few inches except for the rare, upstanding residuals of dune rock. At the seaward edge there is a sharply defined low-tide cliff, along which great blocks of rock are undermined and fall away (Plate VII, fig. 3). I have not been able to investigate the undercutting of the seaward edge, but along the sides of channels eroded through the platform, ledges of rock 8 to 10 feet wide and only a foot or so thick suggest that the surface of the platform is much more resistant than the rock beneath. This is not an original feature, for the dune bedding lies at all angles to the surface of the platform (Plate VII, fig. 2).

At the landward side, the margin of the horizontal platform is defined with knife-edge precision. The platform, being almost entirely covered with a mat of *Hormosira* weed, mussel colonies, and other growths, ends sharply at a gently sloping bare kerf of hard dune rock, which rises as a typical low ramp to the notch in the cliff or in the rock stacks. The level of the platform is approximately mean sea-level,

and that of the wave notch is about high-tide level or slightly above this, due to the sweep of the waves up the ramp (Text-fig. 1).

At all states of the tide at both localities, except when the waves do not cover the platforms, the latter are swept by waves of translation generated in the breaker zone offshore, and often regenerated when the combers reach the outer edge of the platform. At Point Lonsdale, on the " spit " referred to, the water sweeps across the platform with a speed of 5 to 7 knots, which decreases greatly only when the waves are too low to more than " trickle " over it. Similar conditions obtain at Sorrento, except that the cliffs supply debris to the platform, which has many more patches of sand and small stones than are found on the spit, and a correspondingly weaker growth of organisms.



TEXT-FIG. 1.—Generalized section across the platforms in Calcareous Aeolianite. Not to scale.

At both localities and along the coast as far as studied, the dune limestones become progressively indurated with secondary calcite cement between the grains, as sea-level is approached. Two or three feet above high-water level the rock is soft and crushes under the hammer, but at the level of the wave notch it is hard enough in patches to ring when struck, and below this, on the ramp and the platform, the rock is completely indurated, brittle, and sonorous to a depth of 1 to 2 feet below the level of the platform.

That this induration at sea-level is not to be read in reverse as a decalcification above sea-level is clear, firstly because successive layers of dunes separated by old soil horizons occur, and in cliff sections the differences in colour, texture, and degree of compaction of the layers are everywhere distinct, while the old soils are virtually unaltered from their original condition. Also, since the rocks are aeolianites, the induration of the hard layer at sea-level is obviously due to secondary cementation, and " de-cementation " so neatly achieved as to release again the original grains without giving rise to other solution effects would be a difficult achievement for the agents available.

I would attribute the cementation of the dune rock to the precipitation of calcium carbonate from rain-water percolating through it when the fresh carbonated water meets the sea-water that must, because of the porous nature of the rock, penetrate well beneath the cliff base.

Evidence for the saturation of the rock with sea-water at and just above high-tide level is afforded by the continual dripping of such water from the roofs of undercut ledges and low caves excavated below high-tide mark, even from rocks far removed from spray at low-tide.

Macfadyen (1930), Kuenen (1933), and Umbgrove (1947) have referred to the solvent action of sea-water under tropical conditions, while Wentworth (1939) describes coastal benches as formed by the solution of $CaCO_3$ *above* the level of saturation with sea-water, which itself is believed to be saturated with $CaCO_3$. He describes solution benches as generally 2 to 3 feet, rarely 5 to 6 feet, above mean water level, with a tidal range of less than 3 feet. The platforms herein described differ from solution benches in their lower elevation, being approximately at mean sea-level, and in their actual induration, which makes them harder than the rock both above and below.

In the dune rock, water-layer weathering at elevations above the horizontal platform does not take place, for the rock is so porous that pools will not stand on it above the level of saturation. Being calcareous and porous it is unlikely to be affected by alternate wetting and drying, and its high porosity, too, would perhaps reduce the effect of crystallization of salt in the pores, since the crystals would grow into large cavities, and not much water would remain in any case, to form large crystals. The reduction of residuals on the platform, and attack on the cliffs, is largely to be attributed to wave action by quarrying and abrasion, but once the horizontal platform has been produced it cannot be subject to any significant wave attack on its surface, since it remains horizontal almost to the edge of the low-tide cliff. There, however, irregularities appear due to the action of breakers, whereas the waves that cross the platform, being waves of translation, suffice merely to sweep it clear of detritus.

Behind the bar afforded by the " spit " at Point Lonsdale, numerous platform residuals, appearing above sea-level at low-tide, occur for a mile or more inside Port Phillip Bay and extend for several hundred yards into the Bay, from the beach. All are at the same level, which is also the same as the spit, although in the Bay the waves never attain the size of those on the ocean front. It would appear, therefore, that the level of the indurated layer and hence of the platforms is independent of the nature of wave attack, as would be expected if the bench is formed in a definite position relative to mean sea-level.[1]

Ferruginous Cementation.

The formation of a strong coating, up to an inch or more in thickness,

[1] There is evidence at Sorrento for the uplift of a former indurated platform-level by some 4 to 6 feet. No clear indication of this was noted at Point Lonsdale, and the matter will be dealt with more fully in another context.

of secondary limonite on exposed surfaces about sea-level is common where the original rocks are highly ferruginous. Such coatings have been noted, particularly in the shore platforms near Melbourne, developed from Tertiary ferruginous sands, and also at the Forrest Caves, Phillip Island, developed from basalt tuffs. Large surfaces on the shore platform are coated over, and pebbles and shells incorporated in the ferruginous veneer, which is much harder than the original rock. Even the surfaces of small pot-holes may be so coated. The ferruginous deposits undoubtedly have the effect of preserving the rock surfaces on which they form, and the evidence is that they are deposited mainly between low- and high-water level. A difference in colour of the iron oxide cement in the rocks of the cliffs and the coatings is characteristic, that in the cliff being buff or yellowish-red, and that on platforms very dark brown or black.

Wave Action in Platform-formation

On the Victorian coast, and from examples quoted in the literature, it is clear that, considered broadly, waves attack a rocky coast in a broad belt extending from well below low-water level to several feet above high-water. In the breaker zone erosion is clearly vigorous throughout this belt, so that ideally, wave action alone from this zone to the shore should result in a profile consisting of a submarine shelf below low-water level, sloping up continuously to a wave ramp at the shore, up which the waves of translation sweep. That portion of the wave ramp that is exposed between low- and high-water levels is a type of shore platform, and whether or not a wave notch will develop at the cliff base will depend upon local conditions of the rocks, and vigour of waves.

The actual slope of these features, especially the breadth and inclination of the wave ramp, will also depend upon local conditions. Such a profile is expectable in rocks not subject to special effects of weathering or cementation about sea-level, and is generally found in fresh granite, but the surface exhibits marked irregularity due to minor " accidents " in the erosion of joint blocks.

With soft rocks, subject to the attack of strong waves, erosion below low-tide level would be relatively easy, so that the submarine section of the profile should extend very close to the cliffs, and the wave ramp would then be absent, or replaced by a transitory sandy beach which would be scoured during storms. This is the condition on long stretches of the Victorian coast, where soft Tertiary sedimentary rocks occur (Baker, 1943).

Under the special conditions postulated by Bartrum (1935) of strong waves breaking well off-shore and the combers impinging on a cliff, the

final plunge of the combers would, I suggest, result as usual in a wave ramp rather than a horizontal, plane platform, partly because the formation of such a platform would require maximum erosion at a defined level, which is not expectable with variation in wave height, also because the seaward edge of the platform would surely be more eroded than the landward, and again, because even in a tideless sea with waves of constant height, dissipation of energy in waves of translation requires that they form a ramp sloping seaward.

With rocks susceptible to the special effects of water-layer (and water level) weathering about mean sea-level, however, the above described profile is modified. On those parts subject to splash and spray, or exposed between tide levels, many horizontal areas that are swept mainly by waves of translation or swash at the lower elevations are formed. Weathering tends to reduce rocks standing above the level of saturation and, as described above, broad platforms result especially in relatively sheltered positions where wave attack on the seaward edge is not strong.

The waves of translation that pass over such platforms produce little effect in lowering their elevation, but they do strongly attack the bases of rock stacks and the cliff itself. In such attack, the energy of the wave front is partly expended in an upward surge of the " swash ". Where a platform is narrow and the waves strong, the swash may itself operate over a belt at the foot of the cliffs, up to several feet above the platform, resulting again in a wave ramp.

Where the platform is broad and the waves that reach the cliff are more feeble, the upward swash will be effective only on a gentle ramp, and such a ramp will be formed only in soft rocks that can be readily eroded by the weak waves. This condition obtains in the Pleistocene aeolianites at Point Lonsdale and Sorrento. Rock stacks nearer the outer edge of the platform in these aeolianites are, however, subject to stronger attack by the translatory waves, and their bases have only short, steep ramps, or notches.

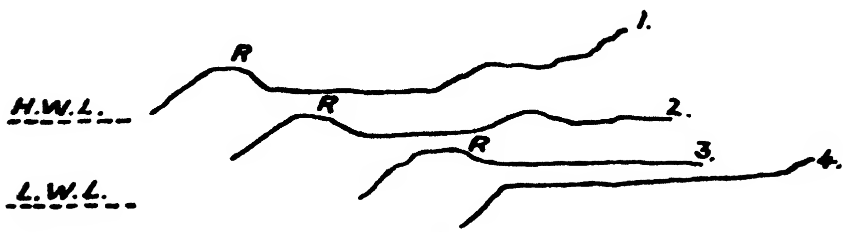
The term " storm-wave " platform is I believe, misleading if it is applied to platforms on open coasts that are subject to severe wave action in the normal course of events, simply because such coasts are also subject to severe storms. Observation indicates that the features of such coasts where they have been studied in Victoria are explicable along the lines indicated in the above discussion, without recourse to the special effects of storm waves, except for minor details. Indeed, much of the destruction of platforms on open coasts must be attributed to storm waves, which have powerful erosive effects over a broad vertical zone.

Bartrum's description of storm-wave platforms includes several factors, but if the concept of wave planation about high-water level or

slightly above, is basic to the definition of the type, the writer would not apply the term as Edwards has done to the Victorian examples studied.

Ramparts.

The presence of low ramparts rising above the general level of platforms at their seaward edges has been noted at many localities (Wentworth, 1938 ; Bartrum, 1935 ; Jutson, 1948). Bartrum's and Wentworth's explanation, that the rampart is preserved because it is wetted more continuously than the rocks behind it seems clearly to be correct, and has important implications. For instance, the rampart could persist in spite of erosion at the platform edge, if the rocks behind it are continuously reduced in elevation by water-layer weathering ; but once they are reduced to water level the rampart could no longer be regenerated if once removed by erosion (Text-fig. 2). Systematic study of ramparts would seem, therefore, to offer a delicate test of the relative importance of weathering and marine erosion in platform development.



TEXT-FIG. 2.—Possible stages in the retreat of the seaward edge of a shore platform, retaining a rampart (R) while the platform remains above the level of saturation, but losing it when reduced to that level.

Additional factors.

Most recent work on shore platforms has been done in the Pacific Region, on shores not subject to severe cold or to the peculiar effects of weathering under monsoonal conditions. It is to be expected that where freezing may occur in winter, different effects from those described will be found, as Nansen (1922) has shown, and in regions of low average temperature, too, the effects of alternate wetting and drying, and of crystallization of salt, may be subordinate. Marine growths may also vary in their vertical range according to the local environment and with different types of organisms. Under monsoonal conditions the effects of very deep weathering should also be noticeable in emphasizing the influence of the level of saturation, and observations in other climatic zones should, therefore, yield significant results. Detailed study of the shores of bodies of water with no or very small tidal range would also permit a clearer analysis of shore processes by removing the effect of one important variable in marine erosion.

SHORE PLATFORM AT SAN REMO

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EXPLANATION OF PLATES

PLATE V.—Exposed coast, San Remo, Victoria, in Jurassic sedimentary rocks, at half-tide. In the foreground, a water-layer weathered surface and shallow pool fed by splash, above HWL. Beyond this, a rough platform just above LWL, that is almost always awash ; on this,

1

2

3

SHORE PLATFORMS AT POINT LONSDALE.

On the Genus *Corynoides* Nicholson

By Isles Strachan (Sedgwick Museum)

Abstract

The Ordovician genus *Corynoides* Nicholson has until recently been very imperfectly known and generally neglected. Its development and peculiar morphology are discussed, but its systematic position amongst the graptolites remains doubtful. Four European species are here described and figured, one being new, and American species are briefly discussed.

THE genus *Corynoides*, erected by Nicholson for some problematical fossils associated with graptolites, has been generally neglected by later workers, specimens being referred to the early figured species without adequate examination of their different characters. In the course of some work on Ordovician graptolite faunas I have had occasion to attempt the identification of species of *Corynoides*, and have realized that they were not at all well-defined. At Dr. Bulman's suggestion I have tried to locate and re-examine the types, and to redefine the characters of the recognized species, interpreting them in the light of his recent work whereby the morphology and development of the genus has been elucidated.

I have been fortunate in obtaining material from various sources. I must thank the authorities of the British Museum (Natural History) and the Department of Geology of Aberdeen University for specimens from the Nicholson collections, the Department of Geology of Birmingham University for some from the Lapworth collection, and the Geological Survey in London and Edinburgh for other material. I must also express my grateful thanks to Dr. Bulman for encouragement and advice throughout the work.

Corynoides Nicholson 1867

(*Corynograptus* Hopkinson and Lapworth 1875)

Rhabdosome composed of a long sicula and very few thecae growing parallel to and in contact with it; sicular and thecal apertures each with a broad, lamelliform process. Apparently confined to the Ordovician and recorded from Europe and North America from the Glenkiln-Lower Hartfell Shales and their equivalents.

Genotype: *Corynoides calicularis* Nicholson (monotypy).

The interpretation of the forms referred to this genus has been a matter of considerable difficulty in the past. Nicholson (1867, p. 108) thought that "*Corynoides* has evidently been composed of a single polypite only", and Lapworth held the same view. Roemer (1897, p. 636) suggested that there were several thecae present and associated the genus with *Cephalograptus*, but Ruedemann was the first to describe

a sicula and several thecae (1908, p. 231). His interpretation, which was followed by Hadding (1915, p. 25), has recently been shown to be imperfect by Bulman (1944, p. 24) who, with well-preserved material from limestone nodules, has been able to give a detailed account of the morphology and development.

There is a very close structural similarity in all the species so far described, and they form a distinct group somewhat removed from the rest of the graptolites.

The development has been fully described by Bulman (1944, 1947) but will be summarized here. The prosicula is of the usual graptolite form but is proportionately longer. It is followed by a very long metasicula whose aperture carries a broad, lamelliform virgella, which is quite distinctive but formed in essentially the same way as the normal rod-like virgella of other graptolites. The first theca develops from a bud which is almost apical on the prosicula and grows down beside the sicula to its aperture where it develops a process similar to the virgella. The second theca arises from the first, near its apex, and crosses over to the other side of the sicula when near the distal end. This grouping of the sicular aperture between two thecae with the three projecting processes is the most adult and the commonest stage observed. A third theca has been seen quite frequently in some species. It develops apparently from the second theca but almost immediately grows into a short, free tube projecting at right angles to the rhabdosome length and does not appear to develop into a normal theca. It was this structure which Ruedemann described as the sicula.

The peculiarities of the genus appear to be (1) the small number of thecae, (2) the presence of the broad process on both the sicula and thecae, (3) the apical position on the prosicula of the first thecal foramen, and (4) the alternating origin of the thecae.

The relationships of the genus are obscure. The alternating development of the thecae precludes any affinity to *Azygograptus* as suggested by Ruedemann, since there the thecae develop in series. Apical initial buds have been observed in a few true graptolites, but only at lower stratigraphical horizons. *Isograptus* shows this character, as well as having elongate thecae with broad apertural processes whose structure is at present not known, and *Corynoides* may have arisen from an isograptid ancestor, inheriting also the alternating development of the thecae. Since the peculiar third theca is of fairly frequent occurrence it can hardly be regarded as an abnormality, and Dr. Bulman has suggested that it might possibly represent the bitheca of a dendroid. Ruedemann has also suggested dendroid affinities for the genus, but it would seem better to leave the family *Corynoididae*, as both these authors do, in the Graptoloidea for the present.

Four species have so far been described from Europe, *Corynoides*

calicularis Nicholson, *C. curtus* Lapworth, *C. gracilis* Hopkinson, and *C. incurvus* Hadding. A new species, recorded as such by Peach and Horne in 1899, is described for the first time below.

The author has been unable to find any material of *C. gracilis*; the whereabouts of Hopkinson's originals is unknown and the only specimens labelled as this species, which are in the Geological Survey collection in Edinburgh, have proved to be monograptid or dimorphograptid stipes. No Ordovician rocks are recorded on Survey maps or in memoirs from the original locality in Dumfriesshire, and Lapworth in 1878 (p. 331) only recorded it with a query. No specimens are known to the author approaching the length assigned by Hopkinson to *C. gracilis* ($\frac{5}{8}$ in. to $\frac{3}{4}$ in., about 16–19 mm.), except var. *maximus* Ruedemann, nor are there references to such in literature other than Hopkinson. Specimens identified as this species by later writers can in all cases be accommodated in *C. calicularis.*

The American species have been listed and described recently by Ruedemann (1947). The following tentative suggestions are made regarding synonymy :—

C. calicularis var. *americana* Ruedemann is probably synonymous with *C. curtus* Lapw., the species to which he referred it in 1908.

C. curtus mut. *pristinus* Ruedemann is probably synonymous with *C. incurvus* Hadding.

C. comma Ruedemann is clearly a valid species, distinctly shorter, broader, and more curved than the typical *C. curtus.*

C. gracilis and its mutation *perungulatus* Ruedemann = *C. calicularis* Nich.

C. gracilis var. *maximus* Ruedemann is represented by a single specimen only, figured natural size, and remains doubtful, for it seems possible that two rhabdosomes are here superposed.

C. tricornis Ruedemann is peculiar in having apparently spines instead of broad processes on the sicula and thecae, and would thus be a valid species.

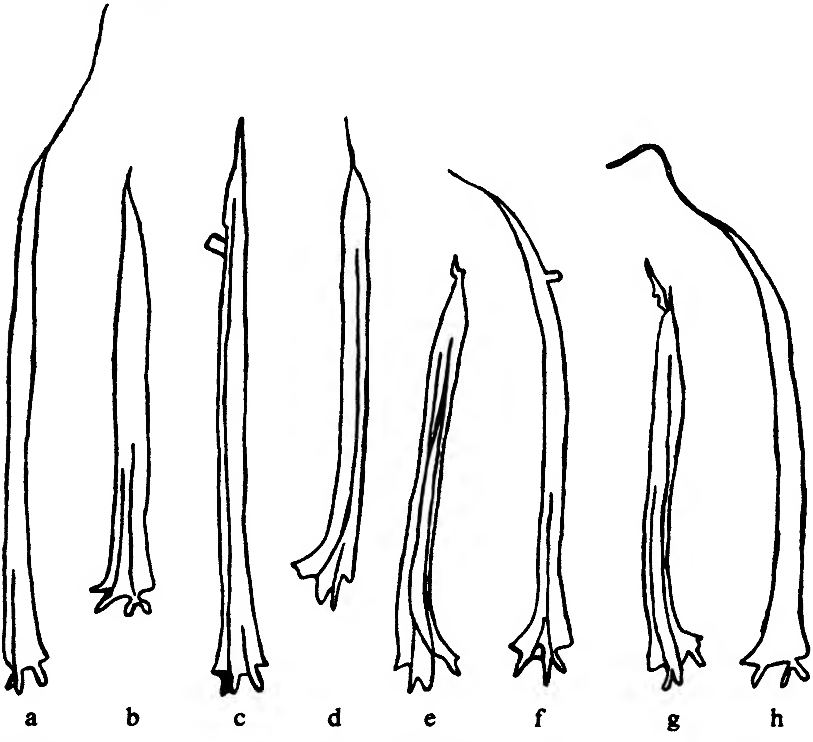
C. ultimus Ruedemann appears to be very close to *C. incurvus* in size and with similar rather broad apertural processes; its late presence in North America cannot, unfortunately, be correlated as yet with European zones.

Fuller synonymies of all species appear in Ruedemann (1947), but many of the references are to faunal lists only, which, in view of the past difficulties, invite further investigation before they can be accepted.

Corynoides calicularis Nicholson

Text-figure 1

1867 *Corynoides calicularis* Nicholson, p. 108, pl. vii, figs. 9–11.
1876 *Corynoides calicularis* Lapworth, pl. iv, fig. 91.
1877 *Corynoides calycularis* Lapworth, pl. vii, fig. 18.
1908 *Corynoides gracilis* Ruedemann, p. 237, pl. 13, figs. 2, 12, 15, 16, text-figs. 133–5.
1908 *Corynoides gracilis* mut. *perungulatus* Ruedemann, p. 239, pl. 13, figs. 3, 9–11, 13, 14, text-figs. 136–139.
1944 *Corynoides* cf. *calicularis* Bulman, p. 27, pl. ii, fig. 12, text-fig. 13.
1947 *Corynoides* cf. *gracilis* Bulman, p. 72, text-figs. 39, 40.
1947 *Corynoides gracilis* Ruedemann, p. 361, pl. 58, figs. 34–37a.
1947 *Corynoides gracilis* mut. *perungulatus* Ruedemann, p. 361, pl. 58, figs. 38–46.
non 1908 *Corynoides calicularis* Ruedemann, p. 234, pl. 13, figs. 1, 6–8, text-figs. 126–131.



TEXT-FIG. 1.—*Corynoides calicularis* Nicholson. × 5. a, b, f, h—P 1933 ; c—H 4107 ; d, e—H 4113 ; g—H 4115. All in the Nicholson Collection, British Museum (Nat. Hist.).

Rhabdosome 9–13 mm. long, with an average breadth of 0·6 mm., widening distally to about 1·4 mm., generally slightly curved.

Horizon : Glenkiln-Lower Hartfell Shales ; Normanskill and Lower Canajoharie Shales.

Lectotype : P 1933, Nicholson Collection, British Museum (Nat. Hist.).

The specimen is labelled in Nicholson's handwriting and is undoubtedly a syntype. Of the individuals on the piece of shale, that shown here as Text-fig. 1*f* is selected as the type.

The rhabdosome consists of a sicula and two thecae, straight or slightly curved throughout their length, with more pronounced curvature at the distal end. The curving appears to be always in the same direction so that the first theca is on the convex side of the sicula. A third theca is frequently developed in this species as a short, free tube.

Nicholson's figures are to be regarded as diagrammatic and cannot be matched with his description or with any of the material in his collection, but Lapworth's figure seems to be a fairly accurate representation of the common form of the species. In spite of considerable variation in length (which is allowed in the original diagnosis) and a rather distinct grouping into two lengths, most of the specimens on a piece of shale being either 8–9 mm. or 11–13 mm. long, the species appears to be a fairly well-defined unit.

As Bulman has recently mentioned (1947, p. 76), Ruedemann's mutation *perungulatus* represents an immature state and both the American forms given above agree well with what is here accepted as *C. calicularis* of Britain.

C. calicularis occurs abundantly at certain horizons in the Moffat Shales, well preserved specimens being especially common in the zone of *Climacograptus wilsoni* (in relief), and in association with *C. caudatus* in the zone of *Dicranograptus clingani*. It is also found in the *Dicranograptus* Shales of South Wales and the Middle Dicellograptus Shales of Jemtland, Sweden.

Corynoides curtus Lapworth

Text-figure 2

1876 *Corynoides curtus* Lapworth, pl. iv, fig. 92.
1877 *Corynoides curtus* Lapworth, pl. vii, fig. 19.
1915 *Corynoides curtus* Hadding, p. 26, pl. iii, figs. 28, 29.
1944 *Corynoides curtus* Bulman, p. 24, pl. ii, figs. 9–11, text-figs. 11, 12.
? 1908 *Corynoides curtus* Ruedemann, p. 240, pl. 13, figs. 4, 17–21.
? 1947 *Corynoides calicularis* var. *americana* Ruedemann = *C. curtus* Ruedemann 1908 (above).

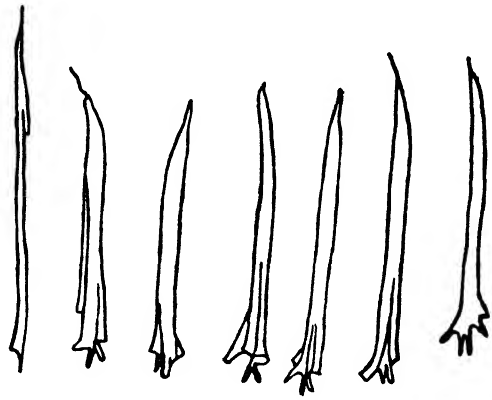
Rhabdosome 6–8 mm. long and 0·4 mm. in average breadth, widening at the distal end to 1 mm. ; generally almost straight.

Recorded by Lapworth and Hadding from the zone of *Dicranograptus clingani* only, but probably occurs at lower horizons as well.

Lectotype : in the Lapworth Collection, Birmingham ; the specimen here figured as Text-fig. 2*d*. This species was never described by Lapworth, and as his figures are natural size there has been some difficulty in determining its characters. Only two pieces of shale labelled as bearing *C. curtus* have come to light as yet, one of which fortunately is in Lapworth's writing and can be regarded as a syntype.

The adult rhabdosome consists of a sicula and two thecae, no trace of a third theca having yet been observed. The details of the thecae cannot be made out from specimens in shale as the preservation is too poor and the individuals are crowded on one another, but the form is very similar to that of the other species.

This species does not appear to be at all common, judging from the



a b c d e f g

TEXT-FIG. 2.—*Corynoides curtus* Lapworth. × 5. a, e, f, g—10638, Geol. Surv., London; b—8139, Nicholson Collection, Geol. Dept., Aberdeen University; c, d—Lapworth Collection, Geol. Dept., Birmingham University.

few specimens which have been found. Those from the Moffat Shales are unfortunately not zonally fixed and appear to be restricted to a few bands where, however, they swarm over the whole surface to the exclusion of all other forms. The horizon of the specimens described by Bulman is not definitely fixed by the associated fauna but is considerably lower than *Dicranograptus clingani.*

The American form is, as was noted by Hadding (1915, p. 26), distinctly more curved than the European ones and is found in beds of Lower Trenton age.

Corynoides incurvus Hadding

Text-figure 3

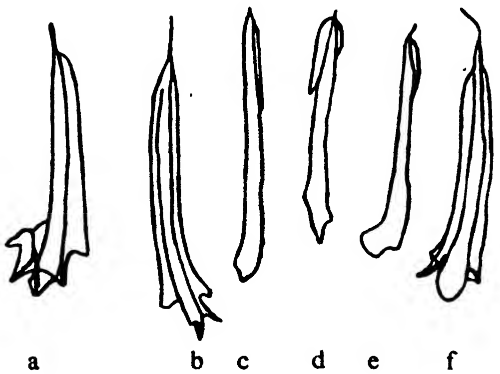
1915 *Corynoides incurvus* Hadding, p. 25, pl. iii, figs. 24–7.
? 1908 *Corynoides calicularis* Ruedemann, p. 234, pl. 13, figs. 1, 6–8, text-figs. 126–131.
? 1947 *Corynoides curtus* mut. *pristinus* Ruedemann - *C. calicularis* Ruedemann 1908 (above).

Rhabdosome 5–7 mm. long and 0·8 mm. broad, slightly curved throughout its length and more abruptly at the distal end, where it widens to 1·5 mm.

Hadding records it from the zone of *Dicranograptus clingani* in Bornholm, and it has now been found in the same zone at Dobb's Linn, Moffat.

Lectotype : Specimen figured by Hadding, 1915, pl. iii, fig. 24; Geological-Mineralogical Institute, Lund.

This species is most easily recognized by its comparatively great



TEXT-FIG. 3.—*Corynoides incurvus* Hadding. × 5. a—8161 ; b, c—8157 ; d, e, f—8156, all in Nicholson Collection, Geol. Dept., Aberdeen University.

breadth. Slightly immature specimens show a thecal arrangement similar to that in the rest of the genus, but the apertural processes appear to be much broader and the distal end in adults is generally distorted by twisting in compression. The proximal end frequently shows the first and second thecae arising at slightly different levels, and the second theca must cross to its own side of the sicula very early in its development.

The American form referred to above is very close to the European ones, so far as can be judged from the published figures and descriptions, and they are probably specifically identical.

Corynoides serpens nov. sp.

Text-figure 4

1899 *Corynoides* nov. sp., Peach and Horne, p. 238

Rhabdosome about 10 mm. long, average breadth 0·5 mm., widening distally to about 1·5 mm. ; strongly curved, semi-circular or S-shaped.

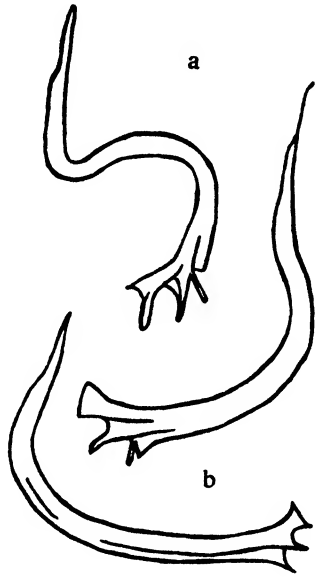
Horizon : Lower Hartfell Shales.

Type : R 5334, Geological Survey of Scotland, Edinburgh (fig. 4*b*).

This species is very close to *C. calicularis* in size and general character, but is easily distinguished by the pronounced curvature shown by all specimens. The associated fauna shows no abnormalities and the curvature can hardly be regarded as an environmental pathological

condition. No other species of *Corynoides* has been found along with it.

All the specimens, which are crowded on several pieces of shale, come from the railway cutting opposite Kirkton, near Abington, Lanarkshire, and are associated with *Orthograptus* cf. *intermedius*, *Lasiograptus* cf. *harknessi*, *Climacograptus* cf. *scharenbergi*, *C.* cf. *miserabilis*, indicating a Lower Hartfell age.



TEXT-FIG. 4.—*Corynoides serpens* nov. sp. × 5. a—R 2148 ; b, c—R 5334, all in the Geol. Surv., Edinburgh.

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New Lower Ordovician Brachiopods from the Llandeilo-Llangadock District

PART I

(PLATE VIII)

By Alwyn Williams

Abstract

The following systematic account of new Lower Ordovician Brachiopods has been divided into two sections. Part I includes descriptions of a new species and variety of *Resserella*, two new Dalmanellas, and two new Horderleyellas, and some notes on the value of B. B. Bancroft's methods of separating Dalmanellid species and genera. In Part II two new species and a new variety of *Hesperorthis*, *Rostricellula*, and *Sowerbyella* respectively are recorded; an investigation of *Orthis turgida* McCoy shows that forms referred to this species belong either to *Corineorthis*, two new species of which are described, or *Paurorthis*.

Introduction

The Lower Ordovician rocks of the Llandeilo–Llangadock area have yielded a rich shelly fauna hitherto largely undescribed. The following systematic account of these new fossils is divided into two parts. Part I is concerned exclusively with Upper Llanvirn-Llandeilo Dalmanellids, in the investigation of which the techniques implemented by B. B. Bancroft in his study of Caradocian forms have been applied. The conclusions as to the efficacy of his ribbing notation are set out as an introduction to this section.

In Part II the remaining brachiopods are described. An investigation of *Orthis turgida* McCoy, two syntypes of which came from this district, has led to the belief that the types include three species belonging to two different genera. In an attempt to unravel the relationships existing between these species it has been necessary to include a description of a Caradocian form from North Wales (*Corineorthis globosa* sp. nov.), which has not been found in the area surveyed.

Acknowledgments

I wish to express my indebtedness to the late Professor H. P. Lewis of Aberystwyth, for his meticulous supervision and constant encouragement throughout this investigation. My thanks go, too, to Dr. C. J. Stubblefield, who gave me considerable advice in the earlier stages of the work and allowed me access to relevant material in the Survey Museum, and who later read the manuscript and made very many valuable comments thereon ; to Professor O. T. Jones, for helpful discussions on the various aspects of faunal distribution ; to Mr. J. C. Challinor, for suggestions in the early stages of the work ; and to Mr. A. G. Brighton, for allowing me access to specimens in the Sedgwick Museum.

The work was undertaken during the tenure of a D.S.I.R. grant, and a University of Wales Fellowship, and to these bodies I express my grateful thanks.

THE ORDOVICIAN DALMANELLIDS

The genotype of *Dalmanella* has long been the subject of considerable controversy, and although there is now general agreement on the status and limits of the genus, it is felt that a brief synopsis of the situation is desirable before entering into a discussion on the Lower Ordovician Dalmanellids.

When Hall and Clarke (1892, p. 205) established the genus *Dalmanella* they named *Orthis testudinaria* Dalman as type. Their generic description, however, was based upon a series of North American shells (= *D. rogata* Sardeson) which subsequently proved to be entirely different. (Schuchert and Cooper, pp. 120–1, who also point out that Meek, Sardeson, and Raymond had all expressed opinions to this effect.)

In 1928 Bancroft erected three genera, namely *Resserella* (genotype *Orthis canalis* Sow.), *Onniella* (genotype *O. brøggeri* Bancroft), and *Wattsella* (genotype *W. wattsi* Bancroft) ; *D. rogata* proved to be an Onniellid and *O. testudinaria* a Wattsellid (Schuchert and Cooper 1932, p. 120).

In 1932 (p. 119 et seq.) Schuchert and Cooper took as genotype for their emended description of *Dalmanella* not *O. testudinaria* which Hall and Clarke had named but *D. rogata*, which they had actually used. Accordingly, Schuchert and Cooper placed *Onniella* in synonymy with *Dalmanella* and *O. testudinaria* became *Wattsella testudinaria*. In this monograph *Resserella* was accepted provisionally as a distinct genus, but some misgivings as to the validity of its segregation from *Onniella* were expressed.

Öpik, however, maintained (1933, pp. 14–16) that *O. testudinaria* must remain the type of *Dalmanella* since Hall and Clarke had named this species as genotype even if it involved modifying the concept of *Dalmanella*. He therefore considered *Wattsella* a synonym of *Dalmanella* and revived *Onniella* for the *D. rogata* type of shell.

Cooper (1942) accepted Öpik's contention. By this time, too, he had come to the conclusion that *Onniella* and *Resserella* were not generically separable and placed the former in synonymy with the earlier founded *Resserella*.

Bancroft (1945, p. 210) refused to recognize *Dalmanella* on the grounds that it was being used in conflicting senses, and in addition to retaining *Resserella*, *Onniella*, and *Wattsella*, erected two new genera, *Soudleyella* and *Raymondella* (preoccupied = *Bancroftina*), and one new subgenus of *Resserella*—*Howellites*.

The differences he cites in the descriptions of these new genera are of great import for detailed zonal work in the Caradocian, but there is no internal change displayed in these Dalmanellids fundamental enough to be at present acceptable as the basis of generic distinction. In this belief the writer provisionally refers all the Caradocian Dalmanellids to the two genera recognized by Cooper (1942), *Dalmanella* and *Resserella* (s.l.), interpreting the latter to include *Resserella* s.s. *Resserella* (*Howellites*), *Soudleyella*, and *Bancroftina*, as well as *Onniella*.

A Note on the Bancroft Notation for the Ribbing System in Orthids (*sensu lato*)

In 1928 [1] Bancroft described a method of enumerating Dalmanellid ribbing systems, and claimed that the notation revealed a series of constant ribbing patterns which have a generic and specific significance. His descriptions of Caradocian Dalmanellids (*sensu lato*), published posthumously in 1945 indicate that he used the notation extensively in definitions of genera and species and the results seemed to confirm his early claims.

The notation was accordingly applied to new species of Dalmanellas Horderleyellas and Resserellas, of Llanvirn-Llandeilo age, collected from the Llandeilo area, and special regard was given to the problems (*a*) why the ribbing split into certain standard patterns, and (*b*) what were the relationships between this older fauna and the Caradocian derivatives.

The answer to the first point seems to be that the tendency to variation in rib patterns is related to the contour of the shell, and is immediately apparent when the notation is applied to the ventral valve as well as the dorsal one (Bancroft used the notation for dorsal ribbing only). The insertion of a rib depends upon the actual slope, and it has been found that branches split off, in the majority of cases, down slope.

[1] The notation can be summarized briefly as follows : Ribs originating at the umbo are termed primaries and are numbered 1, 2, 3, 4, etc., primary 1 being nearest the median line, and primary 4 furthest away. Secondary ribs which split off from the primaries are lettered a, b, c, etc., a being the earliest to split off, b the next, and so on. Tertiary ribs which split off from the secondaries are numbered 1, 2, 3, etc., 1 being the earliest to arise, and so on ; and for ribs of higher orders the numerals continue to alternate with the letters. Thus, 2a1 denotes the earliest tertiary (1), on the earliest secondary (a), on the second primary (2).

Whether the rib splits off on the inside (i.e. towards the median line) or on the outside (i.e. away from the median line) of the parent rib is also very important, and Bancroft used the symbol $^-$ to indicate the inner ribs, and the symbol $^\circ$ to denote the outer ribs. It must be emphasized that the terms " inner " and " outer " sides are always in reference to the *immediate parent* of the rib in question. Thus $2a^\circ$, which is the first secondary to arise on the outer side of primary 2, can bear a tertiary between it and the primary and which, lying on the inner side of its parent, is denoted $2a^\circ1^-$.

For example in dorsal valves with a sinus, primary (1) branches on the inside (i.e. towards the sinus axis). $1\bar{a}$, $1\bar{a}1^{-}$, $1\bar{b}$, 1. In ventral valves with a sharply convex outline, primary (1) is characterized by external branching on either side, e.g. :—

$$1^{\circ}1a^{\circ},\ 1a^{\circ},\ 1b^{\circ},\ 1,\ 1b^{\circ},\ 1a^{\circ},\ 1a^{\circ}1^{\circ}.$$

The operation of such a factor is well exemplified by the ribbing system in genera like *Corineorthis* Stubblefield, where the extreme change in contour in both valves (the dorsal valve has a strong sinus, but is markedly convex, the ventral valve is gently convex medianly and concave laterally) is accompanied by a corresponding change of branching from internal to external in the dorsal valve, and from external to internal in the ventral valve.[1]

A comparison of Upper Llanvirn Dalmanellids with those of Caradocian age shows that there is also a tendency to reduce the number of primaries in more specialized forms which therefore results in a complex secondary, tertiary, and quaternary branching. Forms from the Lower Ordovician have up to 28 primary ribs on a valve (approaching the number in the Orthid protostocks) whereas Upper Ordovician forms described by Bancroft generally have about 14 to 16 primary ribs. Throughout the Ordovician the stocks retained a remarkably uniform outline, so that the reduction in the number of primaries resulted in a more discrete branching system. In other words, primary sectors of Llanvirn and Lower Llandeilo Dalmanellids are always smaller than they are in Caradocian species.

In view of these facts the Bancroft notation is valuable in assessing the stage of development of a Dalmanellid, and in generic discrimination especially when only fragments of external casts are found. This last qualification should be borne in mind because, when abundant material is available, other characters will provide equally good data more easily appreciated. The differences between entire external casts of e.g. *Horderleyella* and *Dalmanella* can be estimated in a glance and need no tedious " counts " to confirm them. In the case of the stage of development, too, the nature of the internal parts tells the story far more quickly and as accurately as notational work.

As far as specific differentiation, based upon notational systems, is concerned, Bancroft seems to have demonstrated that they have a

[1] In Table VIII, columns 1 and 2 (Bancroft, 1945, p. 216), one would expect that since $1b)1a^{\circ}$ and $2\bar{a}1^{-})2b)^{-}$ in the respective ratios 93 and 85 (*Resserella* (s.l.) *inconstans*) to 55·7 and 21·3 (*Resserella* (s.l.) *reushi*) that the former has sharply raised " shoulders " on either side of a narrow mesial sinus and the latter a weakly convex dorsal valve. This is so, and it is the sharp accentuation of " shoulders " in *Harknessella* that contributes in the main to production of ribbing patterns distinct from *Dalmanella* and *Resserella*.

distinct merit, and has used the number and disposition of ribs at the shell periphery, and the early or late insertion of various secondaries, etc., in relation to others for specific distinction. The practice is, however, open to a certain amount of qualification.

The number of ribs present at the shell periphery need indicate nothing more than that the specimen is larger or smaller than another. In the following descriptions it will be seen that *Horderleyella convexa* sp. nov. has a more complex ribbing system than *Horderleyella lata* sp. nov., but it is due to the fact that *H. convexa* is much larger than *H. lata*. A similar relationship exists between *Dalmanella prototypa* sp. nov. and *Dalmanella parva* sp. nov.[1]

The early or late insertion of a rib relative to another, as stated earlier, seems to be related to the contour of a shell. In the case of noticeably distinct shells the eye can appreciate what notational counts confirm, that, for example, the dorsal valve of one species is much flatter than that of another. But, by use of notational studies, it is possible to draw distinctions so subtle that unless they are substantiated by other differentiating characters they may represent variations within an inter-breeding community. Bancroft worked on many hundreds of well-preserved casts to arrive at the norms for each of his species, and there is little doubt that owing to individual variation, especially in so delicate a criterion as the insertion of a tertiary rib, it is necessary to work with large numbers to reach any reasonable conclusion on specific relationships.

Dalmanellacea Schuchert and Cooper 1931

Dalmanellidae Schuchert 1929, emended Schuchert and Cooper 1932, emended Bancroft 1945

Resserella Bancroft 1928, emended Cooper 1942

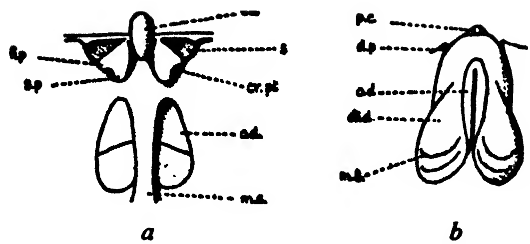
Resserella immatura sp. nov.

Pl VIII, figs. 1–4, Text-fig. 1

Dimensions.—

Syntypes.			*Length.* cm.	*Breadth.* cm.
(1)	Internal mould, dorsal valve	G.S.M. 75,233	1·1	1·3
(2)	External cast, dorsal valve	G.S.M. 75,234	1·2	1·4
(3)	Internal mould, ventral valve	G.S.M. 75,235	1·4	1·4
(4)	External casts, ventral valves	G.S.M. 75,236	Incomplete	

[1] If future work is carried out along these lines it would probably be expedient to accept a standard length of radius from the umbo (e.g. 1·5 cm.), at which to make notational readings. This will have the advantage of ensuring comparisons at approximately the same stage in the development of individuals. Compare, for instance, the considerable differences between readings at the shell periphery, and at a length of 1 cm. from the umbo, in the gerontic syntype of *Dalmanella prototypa* sp. nov. (pp. 168–9).



TEXT-FIG. 1 (*a*).—Cardinalia of *Resserella immatura* (syntype 1) × 3. ad., adductor scar; ca., cardinal process; cr.pt., crural pit; fp., fulcral plate; m.s., median septum; s., socket; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Resserella immatura* sp. nov. (syntype 3) × 3. ad., adductor scar; did., diductor scar; d.p., dental plates; m.t., muscle track; p.c., pedicle callist.

External characters.—Shape: transverse, sub-rectangular with occasional specimens rather longer. Hinge-line straight, wide, with the greatest width of the shell anterior to the hinge-line. Moderately bi-convex, the ventral valve more so, the dorsal valve having an ill-defined mesial sinus. Delthyrium open, inter-areas small, notothyrium open but generally filled by the cardinal process.

Ribbing.—Multicostellate, very fine. Only a small number of well-preserved, entire, external casts have been collected, but syntype 2 seems to be representative,

$$1\bar{a},\ 1\overline{a1},\ 1,\ 1a^{\circ}.$$
$$2\overline{a1},\ 2\bar{a},\ 2\bar{b},\ 2\bar{c},\ 2.$$
$$3\overline{a1a},\ 3\overline{a1},\ 3\overline{a2},\ 3\bar{a},\ 3\overline{b1},\ 3\bar{b},\ 3\overline{b1}^{\circ},\ 3\overline{c1},\ 3\bar{c},\ 3\bar{d},\ 3,\ 3b^{\circ},\ 3a^{\circ},\ 3a1^{\circ}.$$
$$4\overline{a2a},\ 4\overline{a2},\ 4\overline{a1},\ 4\bar{a},\ 4\overline{a1}^{\circ},\ 4\overline{b1},\ 4\bar{b},\ 4\overline{b1}^{\circ},\ 4\bar{c},\ 4,\ 4a^{\circ}\ \text{(strong)}.$$
$$5\overline{a1},\ 5\bar{a},\ 5\bar{b},\ 5,\ 5a^{\circ},\ \text{etc.}$$

the size of sector III is distinctive, it is larger than sector I and II. (In the Caradocian material described by Bancroft the reverse is true.) Shell further ornamented by well-marked concentric growth lines, and by small exopunctae (?) arranged longitudinally between the ribs.

Dorsal interior.—Notothyrial platform small, supporting a cardinal process consisting of a fused myophore and shaft, and bounded laterally by a pair of weak and very small, slightly diverging crural processes each of which has a small crural pit, so that even in mature forms there is no complete fusion of fulcral and supporting plates. Teeth sockets, sharp. The notothyrial platform is continued anteriorly for about half the length of the shell as a mesial ridge. Adductor scars somewhat obscure, subequal; in one gerontic specimen the anterior pair give off to the front a pair of pallial sinuses. Ribbing is apparently confined to the periphery, but in very well preserved specimens is continued very faintly to the muscle scars.

Ventral interior.—Delthyrium moderately deep, hinge-line bearing a pair of teeth bounded laterally by crural fossettes and supported by a pair of dental lamellae which are continued anteriorly as boundaries to the musculature. Delthyrial apex partially closed by a small but conspicuous, triangular, apical plate (pedicle callist). Muscle scar well defined. Adductors lanceolate, separated by a median ridge. Diductors sub-flabellate, elongate, extending anteriorly to enclose the adductors. Ribbing marked on the periphery, and continued very faintly over most of the interior.

Type horizon.—Middle Llandeilian.

Type locality.—Quarry. 550 yards E. of Glan Towy Farm, 3 miles N.E. of Llandeilo.

Resserella immatura var. *plana* var. nov.

Pl. VIII, figs. 5 and 6

Syntypes.			*Length.* cm.	*Breadth.* cm.
(1)	Internal mould of dorsal valve	G.S.M. 75,237	1·7	2·1
(2)	External casts of both valves	G.S.M. 75,238	incomplete	
(3)	Internal mould of ventral valve	G.S.M. 75,239	1·8 (est.)	2·0

The new variety agrees in all respects of internal structure to *R. immatura* ; the persistent varietal differences are the much larger size and the very feeble convexity of both valves. The new variety occupies a definite horizon comprising the lower beds of the Lower Llandeilo.

Type localities.—Small quarry 100 yards N.E. of Pant-y-ffynon Farm, 1½ miles E. of Llandeilo, and old quarry 350 yards E. of Old Dynevor Castle, Llandeilo.

Discussion.—The Llandeilian Resserellas investigated form a more primitive group than the Caradocian material. Four factors render them specifically separable from their derivatives.

(1) *Immaturity of the crural processes*

In Llandeilo forms the crural processes are very small and slender, and even in gerontic individuals show crural pits. The effect is that in moulds the socket line is only moderately or slightly divergent and the pre-socket line slightly sinuated by the crural pit is oblique to the median line.

(2) Obscurity of the dorsal muscle scars.

(3) Pronounced ventral muscle scars.

(4) Well marked pedicle callist. (The pedicle callist appears to be present in some, if not all, Caradocian types but has not been mentioned in descriptions. It is less conspicuous than in *R. immatura.*)

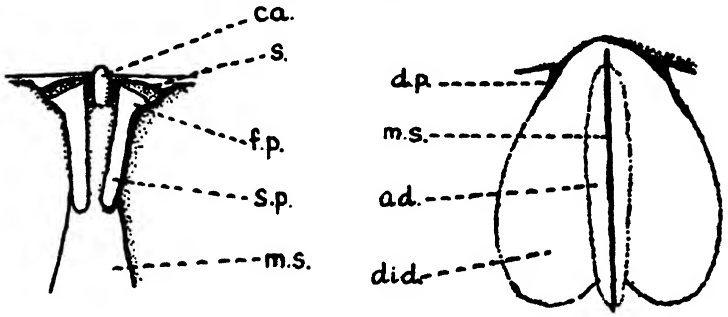
Dalmanella Hall and Clarke 1892, emended Cooper 1942

Dalmanella prototypa sp. nov.

Pl. VIII, figs. 7–10, Text-fig. 2

Dimensions.—

Syntypes.		*Length.* *cm.*	*Breadth.* *cm.*
(1) Internal mould of dorsal valve	G.S.M. 75,248a	0·9	1·1
(2) External cast, complement Syntype (1)	G.S.M. 75,248b	0·9	1·1
(3) External cast of dorsal valve	G.S.M. 75,249	0·95	1·2 (est.)
(4) Internal mould of ventral valve	G.S.M. 75,250a	1·4	1·7
(5) External cast, complement Syntype (4)	G.S.M. 75,250b	1·4	1·7



a *b*

TEXT-FIG. 2 (*a*).—Cardinalia of *Dalmanella prototypa* sp. nov. (syntype 1) × 6. ca., cardinal process; f.p., fulcral plate; m.s., median septum; s., socket; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Dalmanella prototypa* sp. nov. (syntype 4) × 6. ad., adductor scar; did., diductor scar; d.p., dental plates; m.s., median septum.

External characters.—Shape: sub-circular, typically Orthoid, with the greatest width anterior to the straight hinge-line, subequally bi-convex, the dorsal valve almost plane with a well marked sinus, the ventral valve gently convex.

Rib pattern.—Multicostellate. Primitive, the basic element being: primary, secondary (*a*), secondary (*b*), tertiary. This, together with the large number of primaries (up to 14 +) distinguishes it immediately from later Dalmanellids (s.s.).

Dorsal Valve.	*Ventral Valve* (gerontic individual).
	1 ?
$1\overline{a1}$, $1\bar{a}$, $1\bar{b}$, 1.	$2\bar{a}$, 2, 2c°, 2b°, 2b1°, 2a°, 2a1°, 2a2°, 2a2a°, 2a2a1°.
$2\overline{a1}$, $2\bar{a}$, $2\bar{b}$, 2, 2a°.	$3\bar{a}$, 3, 3c°, 3b°, 3b1° 3a°, 3a1°, 3a2°, 3a2a°.
$3\overline{a1}$, $3\bar{a}$, $3\bar{b}$, 3.	$4\bar{a}$, 4, 4c°, 4b°, 4b1°, 4a°, 4a1°, 4a2°, 4a2a°.
$4\overline{a1}$, $4\bar{a}$, $4\bar{b}$, 4, 4a°.	$5\bar{a}$, 5, 5c°, 5b°, 5b1°, 5a°, 5a1°, 5a2°, 5a2a°.
$5\overline{a1}$, $5\bar{a}$, $5\bar{b}$, 5.	$6\bar{a}$, 6, 6c°, 6b°, 6b1°, 6a°, 6a1°, 6a2°, 6a2a°.
$6\overline{a1}$, $6\bar{a}$, $6\bar{b}$, 6.	$7\bar{a}$, $7\bar{a}1$°, 7, 7c°, 7b°, 7b1°, 7°a$\bar{1}$, 7a°, 7a1°, 7a2°, 7a2a°.
etc.	$8\bar{a}$, $8\bar{a}1$°, 8, 8c°, 8b°, 8b1°, 8a°, 8a1°, 8a2°, 8a2a°.
	$9\bar{a}$, 9, 9c°, 9b°, 9b1°, 9a°$\bar{1}$, 9a°, 9a1°, 9a2°, 9a2a°.
	8 more ribs.

Pattern for the above ventral valve at standard length of 1 cm.

2, 2b°, 2a°, 2a1°, 2a1a°.
3, 3b°, 3a°, 3a1°.
4, 4b°, 4a°, 4a1°.
5$\bar{a}$, 5, 5b°, 5a°, 5a1°.
6, 6b°, 6a°, 6a1°.
7$\bar{a}$, 7 7b°, 7a°, 7a1°.
etc.

Dorsal interior.—Notothyrial platform, oval, small, extending as a median ridge anteriorly and supporting a small cardinalia consisting of a cardinal process, and a pair of crural processes. Cardinal process, moderately slender, simple. Teeth sockets not deeply notched. Each crural process consists of an extremely abbreviated fulcral plate and a longer supporting plate (the latter plates form small parallel notches in moulds). Muscle scars obscure. Ribbing deeply impressed in internal moulds of both valves.

Ventral valve.—Umbonal region moderately deep, delthyrium open, dental plates short, well marked, diverging anteriorly. Diductor muscular scars obscure.

In syntype 4, a gerontic individual, the muscle scar is faintly seen to consist of a pair of sub-triangular diductor scars separated by a slender lanceolate adductor scar which extends anteriorly beyond the limit of the diductors.

Type horizon.—Lower *D. bifidus* shales.

Type locality.—Band 40 feet below the Upper Llanvirn Grit, 240 yards W. of Llwyn Bedw Farm, 2 miles E.S.E. of Llandeilo.

Dalmanella parva sp. nov.

Pl. VIII, figs. 11–14.

Dimensions.—

Syntypes.		*Length.* *cm.*	*Breadth.* *cm.*
(1) Internal mould of dorsal valve	G.S.M. 75,251	0·45	0·55
(2) „ „ ventral valve	G.S.M. 75,252	0·5	0·6
(3) External cast of dorsal valve	G.S.M. 75,253	0·4	0·5
(4) „ „ ventral valve	G.S.M. 75,254	0·4	0·5

External characters.—Shape ; sub-circular, typically Orthoid, with greatest width anterior to a straight hinge-line. Dorsal valve gently convex, especially posteriorly, where the shell is raised with two shoulders, one on either side of a distinct mesial sinus. Ventral valve, sharply convex mesially, umbonal region moderately pronounced.

Ornamentation consists of concentric growth lines, and a multi-costellate primitive ribbing system on the pattern, primary, secondary (*a*), secondary (*b*), tertiary.

Dorsal Valve.	*Ventral Valve.*
$1\bar{a}$, 1.	$1a^{\circ}$, 1, $1a^{\circ}$.
$2\overline{al}$, $2\bar{a}$, $2\bar{b}$, 2	2, $2b^{\circ}$, $2a^{\circ}$, $2al^{\circ}$.
$3\overline{al}$, $3\bar{a}$, $3\bar{b}$, 3.	3, $3a^{\circ}$.
$4\bar{a}$, 4.	4, $4b^{\circ}$, $4a^{\circ}$, $4al^{\circ}$.
$5\overline{al}$, $5\bar{a}$, 5.	$5\bar{a}$, 5, $5a^{\circ}$.
$6\bar{a}$, 6, 6a.	$6\bar{a}$, 6, $6a^{\circ}$.
$7\bar{a}$, 7.	4 more ribs.
8.	$6a^{\circ}$) $6\bar{a}$.
9.	$5a^{\circ}$) $5\bar{a}$.

Dorsal interior.—Notothyrial platform sub-parallel, extending anteriorly to form a mesial ridge and supporting a styliform cardinal process and a pair of crural processes. The latter consist of a pair of very abbreviated widely divergent fulcral plates, and a pair of sub-parallel, larger supporting plates. Dental sockets strongly diverging anteriorly, well defined. Adductor impressions generally not evident except faintly in gerontic individuals as a pair of oval bodies. Ribbing deeply impressed on internal moulds of both valves.

Ventral interior.—Umbonal region deep, with dental lamellae well marked, diverging moderately anteriorly. Diductor scars generally obscure, but occasional specimens bear a faint subcordate outline not enclosing the adductors.

Type horizon.—Basal beds of the Lower Llandeilo.

Type locality.—Quarry 300 yards W. of Ysgubor Wen Farm, 1¼ miles E. of Llandeilo.

Discussion.—The new sp. is clearly related to *D. prototypa* but is much smaller, more convex, and the component parts of the cardinalia better developed than in the latter species.

The discovery of these primitive Dalmanellas in strata of Llanvirn age rather complicates the concepts [1] of generic origin within the Dalmanellidae and the relationship that this family bears to the Heterorthidae.[2]

For although the species under discussion are the oldest Dalmanellids (*sensu lato*) found in the Llandeilo area, specimens of *Horderleyella convexa* sp. nov., with highly developed cardinalia and muscle scars, have been collected from strata 100 feet higher than the horizon of *Dalmanella prototypa* sp. nov., and perfectly distinct Resserellas occur at the top of the Llanvirn, along with *Dalmanella parva* sp. nov. It seems unlikely therefore that the *Resserella* or the *Horderleyella* stocks

[1] Bancroft (1945, p. 189): "*Wattsella* (synonym of *Dalmanella*) in which the fulcral plates normally persist to maturity may be regarded as the parent genus of the others" (including *Horderleyella*).

[2] These two families are discussed here in the sense they are used by Bancroft and not as understood by Schuchert and Cooper. The former (1945, pp. 187–9) has advanced valid reasons for the removal of *Horderleyella* from this family, as reconstituted, to the Heterorthidae.

diverged directly from the Dalmanellas, as was previously believed, if they had they would show *initially* the same immaturity of internal structures.

HETERORTHIDAE Schuchert and Cooper 1931, emended Bancroft 1945

Harknessellinae Bancroft

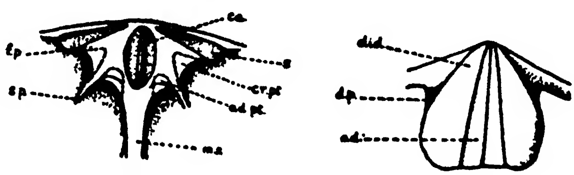
Horderleyella Bancroft

Horderleyella convexa sp. nov.

Pl. VIII, figs. 15–17, Text-fig. 3

Dimensions.—

Syntypes.			*Length.* cm.	*Breadth.* cm.
(1)	Internal mould of dorsal valve	G.S.M. 75,240	1·1	1·6 (est.)
(2)	„ „ ventral valve	G.S.M. 75,241	1·5 (est.)	2·0 (est.)
(3)	External cast of dorsal valve	G.S.M. 75,242	incomplete	
(4)	Internal moulds of ventral and dorsal valves	G.S.M. 75,243	incomplete	
(5)	Internal mould of dorsal valve	G.S.M. 75,244	incomplete	



a *b*

TEXT-FIG. 3 (*a*).—Cardinalia of *Horderleyella convexa* sp. nov. (syntype 1). × 3. ad.pt., adductor pit ; ca., cardinal process ; cr.pt., crural pit ; f.p., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Horderleyella convexa* sp. nov. (syntype 2). ad., adductor scar ; did., diductor scar ; d.p., dental plate.

External characters.—Shape : weakly Harknesselloid, with greatest length at hinge-line which is feebly mucronate. Sub-equally bi-convex, the ventral valve more so than the dorsal valve. Dorsal valve with a well-marked median sinus, the ventral valve slightly carinate mesially. Ribbing, multicostellate, primitive in arrangement, e.g. syntype 3.

$1\bar{a}$, 1.
$2\overline{a1}$, $2\bar{a}$, $2\bar{b}$, 2, $2a^{\circ}$
$3\overline{a1}$, $3\bar{a}$, $3\bar{b}$, 3, $3b^{\circ}$, $3a^{\circ}$.
$4\overline{a1}$, $4\bar{a}$, 4, $4b^{\circ}$, $4a^{\circ}$. -
$5\bar{a}$, $5\bar{b}$, 5, $5b^{\circ}$, $5a^{\circ}$.
etc.

Dorsal interior.—Notothyrial platform, square, rather elevated, passing anteriorly into a median septum, and supporting, posteriorly,

a simple, fairly stout, cardinal process and a pair of crural processes. Each process consists of an inner supporting plate and an outer fulcral plate, both fairly massive and separated by a long narrow crural pit. Dental sockets are sharp, diverging anteriorly. A pair of deep adductor pits, one on either side of the median septum, are each bounded laterally by a scarcely elevated partition which in all probability form diverging anterior extensions of the supporting plates.

The adductor muscle scars are not well defined anteriorly, but consist of a pair of elongated oval bodies. In internal moulds of both valves impressions of ribbing are limited to the periphery.

Ventral interior.—Delthyrium rather deep ; a pair of sub-parallel dental plates extend anteriorly to form boundaries to a sub-cordate diductor muscular impression, which is slightly crenulated anteriorly, and which bounds a centrally disposed adductor scar.

Type horizon.—Upper Llanvirn grits.

Type localities.—Quarry 240 yards N. of the Lodge, almost 2 miles S.S.W. of Llangadock, and outcrops 220 yards E. of Tan-y-garn Farm, 2 miles S. of Llangadock.

Discussion.—The new species differs from those described by Bancroft in a number of aspects, chiefly the larger size of the cardinalia, the traces of anterior extension of supporting plates, the greater convexity of the ventral valve, the limitation of internal ribbing to the peripheral zone, and the more primitive arrangement of the ribs.

Horderleyella lata sp. nov.

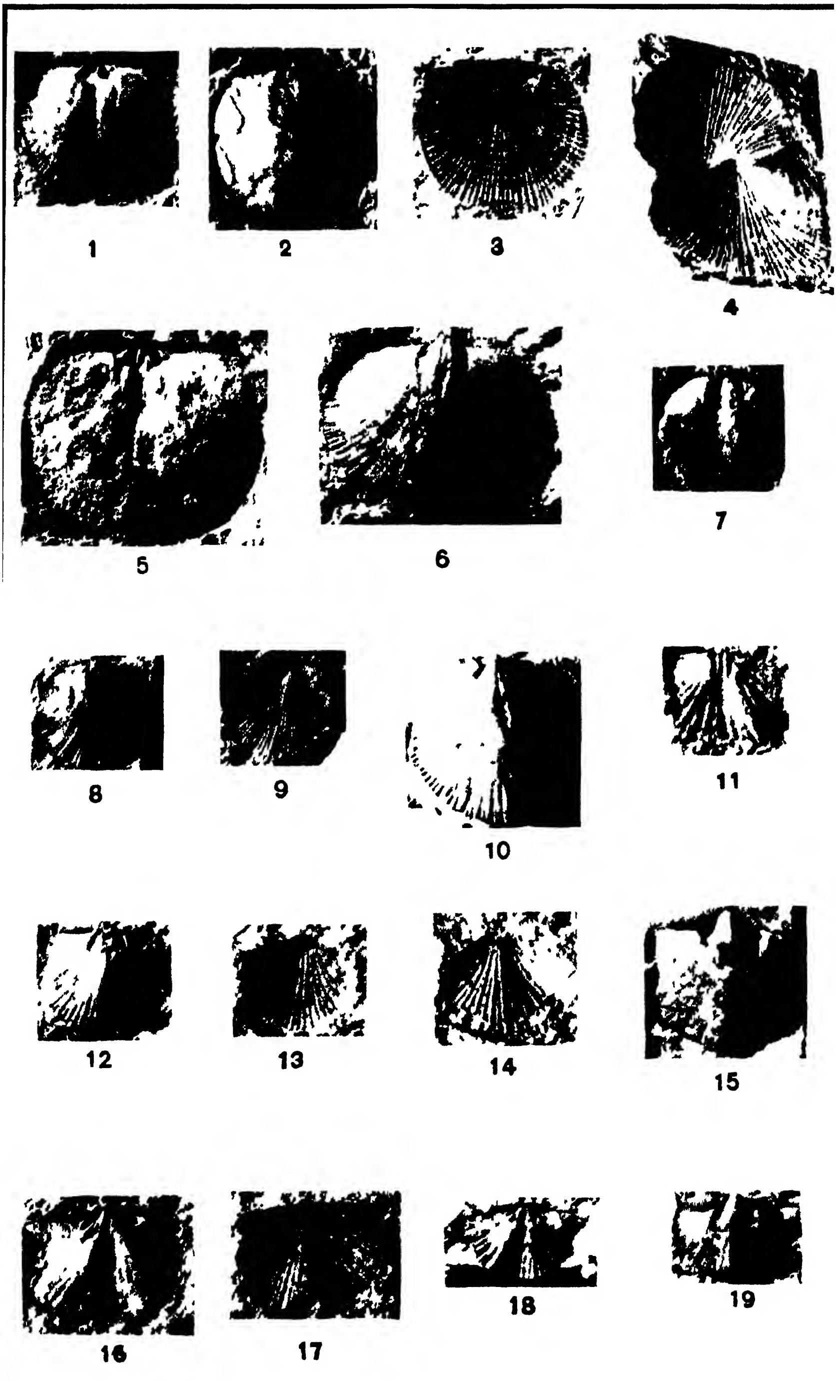
Pl. VIII, figs. 18, 19.

Dimensions.—

Syntypes.			*Length.* *cm.*	*Breadth.* *cm.*
(1)	Internal mould of dorsal valve	G.S.M. 75245a	0·7	1·2
(2)	External cast of dorsal valve	G.S.M. 75,246	0·7	1·2
(3)	Internal mould of ventral valve	G.S.M. 75,245b	0·7	1·2
(4)	External cast of ventral valve	G.S.M. 75,247	incomplete	

External characters.—A small, wide, mucronate Horderleyella. Both valves fairly strongly convex, the ventral valve more so than the dorsal valve. The dorsal valve is impressed by a deep mesial sinus on each side of which occurs a strong lateral fold with the apex to the posterior to give the shell a " shouldered " appearance. Laterally to the folds the shell is flat or almost concave. The ventral valve is carinate, with a strong mesial fold ; flat to concave postero-laterally.

Ribbing multicostellate, primitive in that secondary and tertiary branching is limited. The axes of lateral folding in the dorsal valve fall within section III.



NEW LOWER ORDOVICIAN BRACHIOPODS.

Dorsal Valve.	*Ventral Valve.*
$1\bar{a}$, 1.	$1\bar{a}$, 1, $1a^{\circ}$.
$2\overline{a1}$, $2\bar{a}$, 2, $2a^{\circ}$ $2\bar{a}$) $2a^{\circ}$.	2, $2b^{\circ}$, $2a^{\circ}$
$3\overline{a1}$, $3\bar{a}$, 3, $3a^{\circ}$. 3a) $3a^{\circ}$	3, $3b^{\circ}$, $3a^{\circ}$, $3a1^{\circ}$.
$4\bar{a}$, 4, $4a^{\circ}$. $4\bar{a} = 4a^{\circ}$	$4\bar{a}$, 4, $4b^{\circ}$, $4a^{\circ}$, $4a^{\circ}$) $4\bar{a}$) $4b^{\circ}$
$5\bar{a}$, 5, $5a^{\circ}$. $5a^{\circ}$) $5\bar{a}$	$5\overline{a^{\circ}1}$, $5a^{\circ}$, $5\bar{b}$, 5, $5a^{\circ}$.
$6\bar{a}$, 6, $6a^{\circ}$.	at least 3 more primaries
$7\bar{a}$, 7, $7a^{\circ}$.	
etc.	

Internal characters.

Dorsal interior.—Cardinal process, long, slender, within a spindle-shaped Notothyrial cavity which is supported anteriorly by a well-marked mesial ridge. Dental sockets are fine, widely divergent, and are bounded anteriorly by a pair of crural processes, each consisting of a robust fulcral plate converging posteriorly, and a stout, moderately long, sub-parallel supporting plate. The socket and supporting plates are almost separated by long deep crural pits. Anteriorly the notothyrium is impressed by a pair of adductor pits.

Differentiation of muscle scars is obscure. Ribbing is deeply impressed on internal moulds of both valves.

Ventral interior.—Delthyrium, bounded by a pair of strong dental plates which converge posteriorly at about 80°. Muscular area truncated lozenge-shaped, weakly differentiated.

Type horizon.—Ashes of Upper Llanvirn age.

Type locality.—Ashes in the Long-wood Bethlehem, 200 yards N.W. of Bryn-towy Farm, 1¾ miles S.S.W. of Llangadock.

Discussion.—The new species differs from those described by Bancroft (1945, pp. 235–8) in its transverse form (Bancroft has described a rare transverse form of *H. corrugata* (1945, p. 237) but *H. lata* is even more transverse), its smaller size, the greater convexity of the valves, the relatively larger size of the cardinalia, and the primitive ribbing.

EXPLANATION OF PLATE.

All figures 1½ times natural size except where indicated.

Resserella immatura sp. nov.

FIG. 1.—Internal mould of dorsal valve (G.S.M. 75,233).
FIG. 2.—Internal mould of ventral valve (G.S.M. 75,235).
FIG. 3.—External cast of dorsal valve (G.S.M. 75,234).
FIG. 4.—External casts of ventral valves (G.S.M. 75,236).

Resserella immatura var. *plana* var. nov.

FIG. 5.—Internal mould of dorsal valve (G.S.M. 75,237).
FIG. 6.—Internal mould of ventral valve (G.S.M. 75,239).

Dalmanella prototypa sp. nov.

FIG. 7.—Internal mould of dorsal valve (G.S.M. 75,248a).
FIG. 8.—Internal mould of ventral valve on the same rock specimen as G.S.M. 75,249.

FIG. 9.—External cast of dorsal valve (G.S.M. 75,249).
FIG. 10.—Internal mould of ventral valve (G.S.M. 75,250a).

Dalmanella parva sp. nov.

FIG. 11.—Internal mould of dorsal valve (G.S.M. 75,251) × 3.
FIG. 12.—Internal mould of ventral valve (G.S.M. 75,252) × 3.
FIG. 13.—External cast of ventral valve (G.S.M. 75,254) × 3.
FIG. 14.—External cast of dorsal valve (G.S.M. 75,253) × 3.

Horderleyella convexa sp. nov.

FIG. 15.—Internal mould of ventral valve (G.S.M. 75,241).
FIG. 16.—Internal mould of dorsal valve (G.S.M. 75,240).
FIG. 17.—External cast of dorsal valve (G.S.M. 75,242).

Horderleyella lata sp. nov.

FIG. 18.—Internal mould of dorsal valve (G.S.M. 75,245a).
FIG. 19.—Internal mould of ventral valve (G.S.M. 75,245b).

(*To be continued.*)

A "Luxullianite" from East Dartmoor

By F. G. H. Blyth

(PLATE IX)

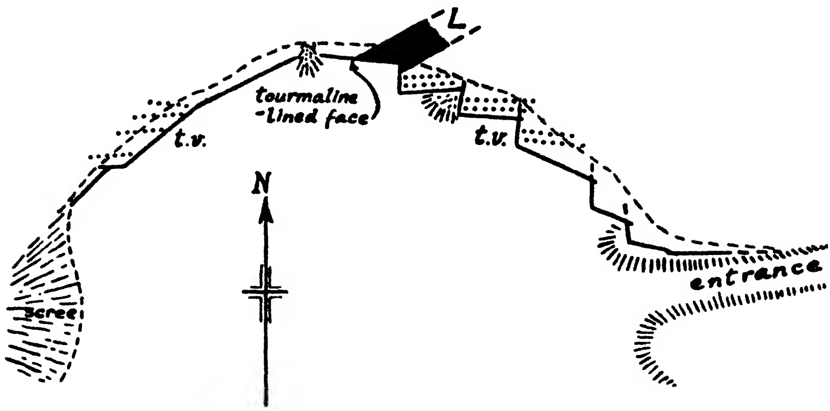
Abstract

A dyke-like mass of luxullianite type is emplaced along a line of fracture which crosses granite in a zone of pneumatolytic reddening, and is exposed in a quarry face. Extensive tourmalinization is related to post-emplacement fractures which traverse both the luxullianite and the adjacent rocks.

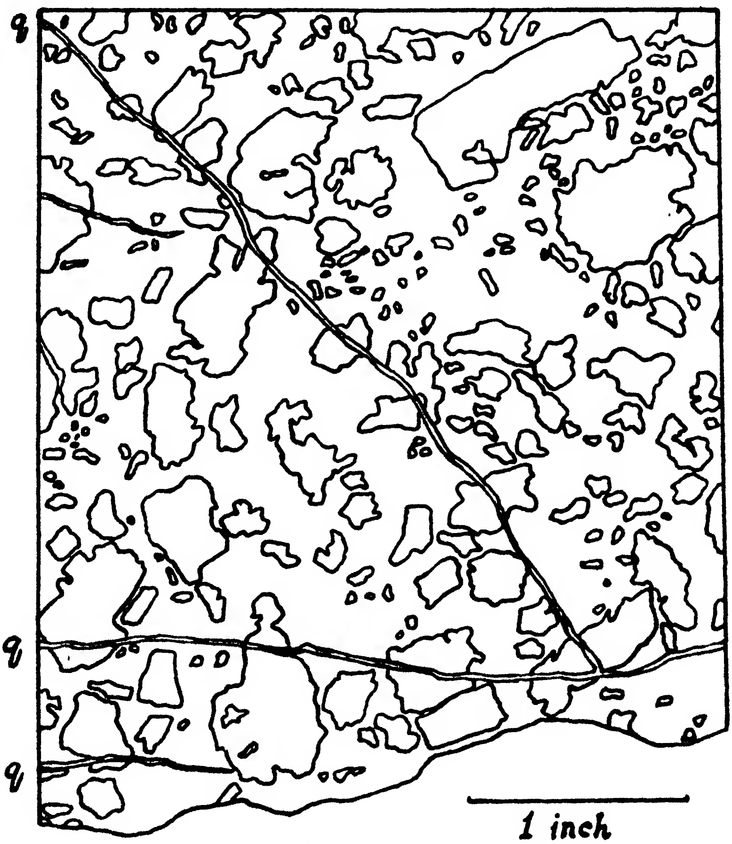
An opportunity was recently taken by the writer of re-visiting a locality near Holne, which was pointed out to him by Dr. A. Brammall some years ago, and of collecting material of luxullianite type there. The occurrence is of considerable interest and was briefly recorded by Brammall (1928, p. 38), but has remained undescribed. The following account makes special reference to the structural relationships between the luxullianitic and neighbouring rocks.

The luxullianite from the Cornish type-locality, where it is found as loose blocks or boulders, has been known for many years from the writings of Bonney (1877), Flett (1909), and others ; in a recent paper Wells (1946) has described details of its texture and microstructures. The Dartmoor "luxullianite" forms a belt of hard rock which traverses granite in the Reservoir quarry of the Paignton Waterworks, 1¾ miles to the north-west of the village of Holne. This quarry, which was opened up at the time of the construction of the dam and reservoir nearly fifty years ago, lies to the north of the Holne–Hexworthy road and within the waterworks enclosure. It reveals a section across a reddened and gently pneumatolysed zone which locally affects the normally grey granite. Within the zone of reddened rock, in the north-east corner of the quarry and intersecting the quarry-face, is the steeply-inclined dyke-like mass of "luxullianite", 3 feet to 4 feet in width. Its relationship to the adjacent rocks can be inspected here, but its continuation on the opposite (western) face of the quarry is obscured by loose blocks and slipped soil. The shape of the rock-face is shown in Text-fig. 1.

The main quarry-rock is a medium-grained, feebly porphyritic biotite-granite, which is crossed by joints trending nearly north–south and east–west. Cutting the granite also, in the northern part of the quarry, are many thin tourmaline veins which are vertical, or nearly so, and strike between N. 80° E. and east–west. In the region of the tourmaline veins the quarry-rock is reddened and carries patches of quartz-schorl aggregate. The luxullianitic band on its northern side crosses the reddened granite along a steeply dipping surface which



TEXT-FIG. 1.—Sketch plan of northern part of the Reservoir Quarry, near Holne. Reddened granite, unshaded. Luxullianitic band (*L*), black. Tourmaline veins (*t.v.*) shown by lines of dots. Width of quarry shown, about 60 feet.



TEXT-FIG. 2.—Textural outline of part of the "luxullianite" block described in the text, natural size, to show corroded felspars (enclosed areas) in tourmaline-quartz matrix. *q* = quartz vein.

strikes N. 65° E., and probably occupies a fracture or fracture-zone having this direction. The junction on the south side is less clear, but the "luxullianite" there appears to grade into, or be welded on to, the reddened granite. Some 10 feet to the south (near the entrance shown in Text-fig. 1) the quarry-rock is not reddened, but is traversed by thin tourmaline veins and carries clots of quartz and tourmaline.

The luxullianitic band is traversed by nearly east–west tourmaline-lined joints, and normal to their surfaces the rock is penetrated by coarse quartz-schorl aggregate, generally to a depth of about ½ in. but in places irregularly to more than twice that distance. These tourmaline-lined joints are parallel to the thin tourmaline veins in the granite, referred to above; the general east–west direction which they possess in common is a regional one, and is locally the trend of a zone of tourmalinization and pneumatolytic reddening which can be seen, for example, traversing the granite of the moor two-thirds of a mile to the east-north-east, in the valley of the River Dart, near Sharrah Pool. A continuation of this zone still further east would take in the quartz-schorl reef known as Leigh Tor.

The "luxullianite" itself is a hard, massive rock, of entirely different texture from that of the adjoining granite, and consists essentially of porphyritic crystals of pink felspar set in a black tourmaline-quartz matrix. The porphyritic felspars range in length from about ½ in. up to 1½ inches, and are larger than the felspar phenocrysts in the quarry granite; while they are sensibly rectangular in many cases, their edges are commonly fretted and penetrated by growths of quartz and schorl which have partly replaced them (Text-fig. 2). Sporadic areas containing smaller felspars of felspar fragments lie between the larger felspars, and may be relics of the groundmass of the original rock before it was transformed by pneumatolysis, or in some cases broken fragments of larger crystals.

Many of the felspar phenocrysts have been fractured, the several parts of a single crystal being cemented together by the quartz and schorl of the matrix. More minute cracks traversing some of the felspars are sealed by hair-like "veins" of black tourmaline. Not all the fractures are regular, but many are aligned parallel to the vertical tourmaline-filled joints which, as already stated, cut obliquely across the luxullianitic band in a nearly east–west direction. This fracturing is clearly of later date than the emplacement of the "luxullianite", and has been an important factor in the progress of the tourmalinization. In this connection it may be recalled that Wells (1946, p. 193) refers to mechanical shattering as probably an important process which, in the Cornish case, facilitated the passage of pneumatolytic material through the rock.

The tourmaline of the matrix occurs partly as stout black acicular

crystals which in thin section show blue and brown colour zoning. Larger tourmalines, developed at the expense of felspar, penetrate the felspars and in some cases enclose small ones. Many smaller tourmaline prisms lie in the clear quartz of the matrix [1]; characteristic radiating clusters of *minute* schorl needles are less abundant than in the type luxullianite. It is not proposed to describe further the microscopic details of replacement in the Holne rock, as it would largely repeat much of the description already given by other writers. Comparison of specimens shows that the proportion of felspar in the Holne rock is, on the whole, somewhat higher than in the Cornish luxullianite, though virtually equivalent areas from each could be selected. The two rocks resemble one another in that they both record the tourmalization of a granite arrested at the stage at which the large felspars had just begun to be affected.

Many of the details mentioned above are seen in a large specimen obtained from the Reservoir quarry, on which a smoothed face measuring 10 inches by 8 inches has been prepared (Plate IX). One edge of the specimen is bounded by an east–west tourmaline-lined joint, and in this part of the mass radiating groups of large acicular schorl crystals are well developed, their length in some cases reaching nearly an inch. A further feature shown by this specimen is the presence of thin quarz veins, some of which are seen in Text-fig. 2, which cross all the other structures and represent a still later fracture-system which was impressed on the rock.

Conclusions

The Holne occurrence is a tourmalinized granite of luxullianite type, and is developed along a narrow belt of severe pneumatolysis which follows a line of fracture; it is itself broken by post-emplacement fractures with which further extensive tourmalinization is associated. The following sequence can be inferred from a study of the Reservoir Quarry exposures :—

(i) Feeble pneumatolytic reddening of the quarry granite in a zone seen in the northern part of the quarry.

(ii) Fracturing in an east-north-easterly direction, followed by the injection of granitic material (bringing with it the porphyritic felspars), and its transformation by the action of tourmalinizing agents passing through the mass.

[1] A spectroscopic test on a crushed sample of the matrix revealed the presence of tin as a very strong trace, and of copper and vanadium as weaker traces. The reddened felspar showed only feeble indications of tin and copper. For making these determinations I am indebted to Mr. A. P. Millman.

(iii) Subsequent shearing of both the luxullianitic band and the adjacent reddened granite along nearly east–west vertical surfaces, which became channels for further penetration by tourmaline-forming fluids.

This sequence may have occupied a relatively short space of time during the local phase of pneumatolysis. The east-north-east direction is one locally followed by many well-developed joints, with which pneumatolytic reddening is commonly associated; east–west fractures are also often characterized by reddening and tourmalinization.

The above conclusions point to the operation of stresses at the locality (and probably over a wider area) at a late stage in the cooling history of the granite, contemporaneous with the tourmalinization. This deduction is in agreement with the opinion expressed by Brammall and Harwood (1925, p. 329), that during the closing phase of pneumatolysis the granite of east Dartmoor was affected by stresses and the resulting fissures afforded passage-way for fluids and gases from depth.

A mechanism such as that outlined, in which intense tourmalinization is localized along a zone of fracture, provides a possible basis of explanation for other occurrences of luxullianite.

ACKNOWLEDGMENTS

The writer's thanks are due to Professor H. H. Read for facilities afforded in connection with the preparation of specimens. The surfaced block described in this paper is housed in the Museum of the Department of Geology, Imperial College, London. The photograph forming Plate IX was taken by Mr. J. A. Gee.

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EXPLANATION OF PLATE.

"Luxullianite" from the Reservoir Quarry, Holne. Reddened felspars in a black quartz-schorl matrix. Approximately natural size.

"LUXULLIANITE" FROM THE RESERVOIR QUARRY, HOLNE.

An Early List of Strata by William Smith

By J. A. Douglas and L. R. Cox

Abstract

An account is here given of the recent discovery at Oxford of a hitherto unrecorded MS. in William Smith's handwriting, giving the list of Strata as known to him in 1797 and differing in some respects from the famous list dictated by him two years later at Bath to the Rev. B. Richardson and the Rev. Joseph Townsend, a copy of which is preserved in the Geological Society's collection. The list is reproduced here in its original form and spelling, together with a number of annotations.

I.—Introduction

His nephew and biographer J. Phillips [1] has recorded how William Smith had decided by 1797 to write a treatise on the stratified rocks of this country and was considering how best to set about it. Various passages dating from this period and intended for the introduction to the proposed work have been published by Phillips [2] from the original MSS., and a further document, consisting of the greater part of this introduction as revised a year or two later, has been reproduced by one of the present writers.[3] An early and hitherto unquoted MS. in Smith's handwriting which has recently come to light at Oxford is clearly a preliminary outline of the second part of the proposed work, which it was intended should "enter into the particulars of each stratum" [4]; it indicates those geological formations which Smith had learnt to distinguish at the time it was written. The MS. is enclosed in a paper folder, bearing the words "Original Papers on Strata". The date 1797 which appears on the sheet headed "Chalk Strata" may be confidently accepted as approximately that of the entire MS. except for a few minor corrections and additions (one bearing the date 1799) which are in darker ink and thus easily distinguishable from the original writing. The MS. is therefore two years earlier than the now famous list of strata which Smith dictated at Bath to his friends Richardson and Townsend in June, 1799, and appears to be of sufficient interest to publish. It is reproduced below, with a series of annotations appended to it. The 1799 corrections are omitted except in a few places where they completely obscure the original draft. The MS. starts with a draft of the title of the proposed work, followed by three

[1] *Memoirs of William Smith*, pp. 21–22 (1844).
[2] Op. cit., pp. 18, 23–6.
[3] L. R. Cox, *Proc. Yorks. Geol. Soc.*, xxv, pp. 81–90 (1942).
[4] See Phillips, op. cit., p. 21. Phillips misquotes the MS. where it refers to the proposed contents of the first part of the work. The MS. reads: "The first . . . should treat of the structure of the earth in a general way." Phillips replaces the word "structure" by "strata".

alternative drafts (the last two crossed through) of the title of its second part.

II.—The Manuscript

Natural order of the Strata
or Structure of the Earth
deduced from practical Observations
from which are also drawn
some Remarks on the Deluge
part 2nd.

Or.

Strata of the Earth
delineated in its
Natural Order
by Wm. Smith Landsurveyor

Strata of the Earth
delineated
from Observations on
Nature
by Wm. Smith Landsurveyor

An accurate delineation of
Terraqueous Strata
from observations on
Nature
by W. S—— Landsurveyor

[Aug.] (1) 15th 1797 No. 1

Chalk Strata

As the immense Quantity of Chalk which composes that range of high Hills that stretch from the low Grounds in   shire thro' Bedfordshire Buckinghamshire Berkshire Wiltshire and Dorsetshire to the Sea forms one of the leading features of this Kingdom—I intend to make those Hills the leading Feature of this work and by making it the first Number in my list of the Strata this being a Bed whose colour nor quality cannot be mistaken making it much fitter for that purpose than any Stratum I am yet acquainted with more especially as my observations have hitherto been confined chiefly to the Western side of these hills.

No. 2

1st Bed of Sand & Sandstone from the Chalk (2)

This Stratum of Sand found near the foot of the Chalk hills is well known as the basis or under Stratum to the Fertile Sandy Land described in Mr. Davis's (3) very sensible report on the state of agriculture in Wiltshire.

No. 3

Clay (4)

This Stratum of Clay or perhaps [sentence uncompleted].

No. 4

Stratum of fine Sand (5)

of a lightish yellow colour with thin Beds of Stone (used for paving & slate) imbeded [*sic*].

No. 5

Thin Beds of shelly Wall Stone (6)

imbed in Clay or clayey sand.

No. 6

Upper Bed of Bastard Freestone (7)

I think the Rubbishy Stone-brash Beds nr. Churchill &c which lie immediately upon a Strong Blue Clay must be the same as the bottom Beds of the Rocks near Cottage Crescent &c in Somersetshire.

No. 7

Blue Clay with Talk imbeded (8)

This Clay or rather Clayey Marl is always found to accompany the upper Bed of the Bastard Freestone in the manner described in the sections annexed. By the openings which have been made into it at the Cottage Crescent & by the side of the Wells Road at 4¼ Miles from Bath and the new Road from Bath to Bradford it does not appear to be more than   feet thick of a darkish blue colour & rather lamilated. A specimen which I tried did not effervesce with ascids. The most remarkable thing which distinguishes it from several beds of the same appearance is the Natrum Selinite or Rhomboidal Selinite which I have found imbed in it at the first two places above described & the Revd. Mr   an engenious friend of mine has also found it in great quantities in the same bed near Bradford.

No. 8

Yellow Clay & Clayey Stone &c (8)

This Stratum or rather Class of Stones [&] Clay alternating with one another seem to partake of the colour and quality of the Fullers Earth which lays immediately under.

[No.] 9
Fullers Earth

This very useful and highly prized Earth is found in great abundance in many.of the wet sidelaying Lands near the Tops of the Hills about Bath it is never found far from that tier of springs which Issue from the upper Stratum of Freestone and the place where it lays may be easily distinguished by the poverty of the surface which I have often observed to be some of the worst Land in the neighbourhood of Bath.

No. 10
Light blue Clay (9)

1797 No. 11
Bastard Fullers Earth (9)

The Bed of bastard Fullers Earth which was found in sinking the Shafts and Cistern for the Caisson (10) at Combehay and also in the bottom of the place where the Caisson was built and which appears in different parts of the cutting thro' Blacklands Furlong Barnards and Sabins Tynings does not lay much above the under division of the Freestone or Bastard Freestone Rock in this neighbourhood.

No. 12
Lower Bed of Bastard Freestone (11)

This class of Stones or division of the Freestone Grit is composed of several thick beds of diferent degrees of hardness and of diferent Qualitis the top bed which lays immediately under the Clay is a Hard greyish Limestone full of Clayholes and generaly incrusted with petrifactions from the hard water which filters thro' the incumbent Clay and this to such a degree as to cement the Rocks together so as to be seperated with great dificulty. This is comonly called by the Quarry men burnt stuff tho it has much more the appearance of Ice and in some places assumes the shape of Isciles which are generally hollow within with a drop of clear water at the end of each.

No. 13
Sand & Sandburs (12)

This Stratum of Ferruginous Sand or Sandy Stone which in some places has beds in it hard enough for building is abt. 30 ft. thick and lays immediately under the Bastard Freestone is of a brownish yellow Colour very compact in the upper part with a little soft which calcarious matter between the joints the middle part is softer in veining with hard burs between and the joints of the sand & sides of the Burs are often deeply tinged with Feruginous matter. This part of the sand is damper than the top and tho firm enough to form Caves in without [word

illegible] is not so close and firm as the top nor so hard as the bottom beds some of which cannot be cut with Steel. These beds have large open joints between them disposed in the same regular manner as was observed in the Freestones & Chalk and serve as the Channels for that water which is the abundant supply of the numerous springs Issuing from the bottom of the sand.

No. 14

Light blue sandy stuff (13)

No. 15

Clay mixed with sandy particles & Ochre-balls (13)

No. 16

Blue Marl

No. 17

Blue or grey Lias

No. 18

White Lias

This Stratum is composed of thin Beds of fine grained stone imbedded in Clay in the same manner as the Blue Lias just described and partakes of the same qualities tho some of the Beds are nearly as white as Chalk and not much harder when first taken out of the Quarry—but when dug in the summer & properly dried makes excelent stone for building or paving Houses and is much used for both purposes in Somersetshire and if well dressed looks very neat but some Beds are much to be preferred to others. This Stone is so very comon in Somersetshire and has been so long wrought that the Quarrymen know the exact Number of Beds and have assigned to each a name—the fowllowing are the common appelations about the Timsbury & Camerton Coalworks.

No. 19

Black Marl (14)

Tho' this stratum is well known in Somersetshire and its good effects as a Manure have been long felt in diferent parts of the Country yet the above term cannot give a Stranger a correct Idea of the substance tho, it may point out it[s] properties.

No. 20

Red Ground (15)

This is the most bulky Stratum for Coal in Somersetshire having been found in some places near 30 fathoms thick and tho it is nearly of the same colour throughout it differs matterially in quality some parts of it being a sharp sand others a tenacious Clay some of a stony consistence & others a perfect flat beded Stone which may be taken up in large Flags fit for building.

21

Millstone (16)

The Millstone seems to be lodged or imbeded in the upper part of the Stratum of Red ground which runs thro' this Country and which I conceive to be of an Irony Quality. A great part of Mendip is composed of Limestone Rocks the Fragments of which it should seem fell in the way of the Irony particles united with it and formed this uncommonly hard Cement or Stratum of concreted matter which about Mendip is called the Millstone and which is evidently composed of part Limestone and part Ironstone and which perhaps if it was burnt & pulverized would form a good cement for building in water. How it comes to pass that this stone is not so thick and of a diferent form in the Measures which it should be found in about Camerton and other Coalworks as it is nearer to Mendip I am at a loss to account.

No. 22

Pennant Stone (17)

This laminated Stone of a greyish colour and gritty Quality is found under the red Ground and generally divided from it by a Bed of yellow tough Clay—called by Colliers " the tops of Cleeves ".

No. 23

Greys (18)

No. 24

Iron Stone

No. 25

Clift (19)

26

Coal

27

Coal

Many Writers have taken great pains to examine into the Component particles of Coal in order to account for its formation and finding many vegitable impressions in its concomitant Strata have thence judged it to be of vegitable origin and puzzled and confounded themselves and their readers with many unnecessary perplexities concerning it unless they could tell what formed Freestone Limestone Clay Ironstone or any other Mineral Body as well as Coal for there is not a doubt but they were all formed at the same time as the great Mass was formed of which Coal is no insignificant part not lying in heaps as many have imagined but regularly dispersed throughout such parts of the Globe as the Creator of all things thought fit to place them in.

28
Limestone (20)

III.—Annotations to the MS.

(1) The margin of the sheet has been trimmed and the month cut away. A second copy of this page is, however, among the Smith MSS. and bears the complete date Aug. 15th, 1797.

(2) The Upper Greensand.

(3) Thomas Davis of Longleat, Land Steward to the Marquess of Bath and author of the Board of Agriculture Report, " General View of the Agriculture of Wiltshire."

(4) Probably the Gault. At this period Smith had met with this formation in a brickyard at Crockerton, south-west of Warminster, and in an exposure near the Black Dog Inn, south of Standerwick, on the Warminster–Bath road. He may also have seen exposures of the Oxford or Kellaways Clay and confused them with the Gault.

(5) No doubt No. 4 referred to some exposure of beds of the Forest Marble series. The brief description given does not quite tally with the typical Hinton Sand of the Hinton Charterhouse district, which constituted Stratum 4 of Smith's 1799 list.

(6) The Forest Marble. It may be noted that this name is not used in the present list, although introduced in the 1799 list.

(7) The Bath Stone. When this MS. was written Smith was living at Cottage Crescent, on the northern flank of Odd Down, Bath, and there were several Bath Stone quarries in the immediate neighbourhood. He goes, however, astray in correlating this formation with the freestone (Chipping Norton Limestone) quarried near his native village of Churchill, in North Oxfordshire. In a note added in 1799 to the present MS. he goes still further astray in correlating the Bath Stone with the freestone (Inferior Oolite) of Frocester and Birdlip Hills, in the Cotswolds.

(8) Formations 7 and 8 are now grouped together as Upper Fuller's Earth Clay. Smith knew the Fuller's Earth in greater detail than any other formation, for Cottage Crescent was built upon it and much of his canal passed through it.

(9) Formations 10 and 11 are the Lower Fuller's Earth Clay.

(10) Robert Weldon's ingenious but unsuccessful Caisson on the canal at Combehay is described and illustrated in J. Billingsley's " General View of the Agriculture of the County of Somerset " (1797), p. 317, pl. xv.

(11) The Inferior Oolite.

(12) The Midford Sands.

(13) Formations 14 and 15 of this list are omitted in the 1799 list, where they are presumably included in the Blue Marl.

(14) The Rhaetic.

(15) The Keuper Marl.

(16) The Dolomitic Conglomerate.

(17) As in the 1799 list, the Pennant Stone is placed above the Coal Measures, although Smith well knew that in the collieries near High Littleton, where he had worked for several years, the Coal Measures are overlain directly by the red marls of the Trias. There are, of course, two series of Coal Measures in Northern Somerset, one above and one below the Pennant Grit.

(18) A local miners' term for hard carbonaceous grit of the Coal Measures.

(19) A local miners' term for hard, laminated, black, or grey shale with plant remains.

(20) The 1799 list ended with the Coal. It is, therefore, interesting to see that in 1797 Smith correctly placed the Carboniferous Limestone below the Coal Measures, although a few years later he was less certain of its position. (See Cox, *Proc. Yorks. Geol. Soc.*, xxv, p. 29 (1942).)

IV.—Concluding Observation

The list of formations in the MS. reproduced above compares very closely with that dictated by Smith to Richardson and Townsend in 1799.[1] The differences between the two lists may be summarized as follows.—Stratum 5 of the 1799 list (" Clay "—probably a clay of the Forest Marble series, as the position, above the Forest Marble, is wrong for the Bradford Clay) is omitted in the present list. Stratum 10 of the present list is omitted in the 1799 list, where it is, no doubt, included in " Bastard Fuller's Earth and Sundries ". Strata 15 and 16 of the present list are also omitted in the 1799 list, where they are probably included in the Blue Marl. Stratum 24 (" Ironstone ") is similarly omitted in 1799 and probably included under " Grays ". Two numbers (26 and 27) are allotted to the Coal in the present list, and only one in the 1799 list. Stratum 28 (" Limestone ") is, as already mentioned, omitted in the 1799 list.

It is thus clear that the main details of the succession around Bath which Smith gave in 1799 had already been known to him for several years—probably since 1793 or 1794. From 1794 to 1799 he was occupied with the exacting duties of Resident Engineer to the Somerset Coal Canal Company, and his geological observations were necessarily confined to the formations excavated during the construction of the canal and such exposures as he could examine between Bath and the

[1] This list has been reproduced several times, e.g. by Smith himself, *Memoir to the Map and Delineation of the Strata*, table facing p. 8 (1815), and by T. Sheppard, *Proc. Yorks. Geol. Soc.*, xix, table facing p. 127 (1917).

canal, and on very occasional journeys along the Bath–Warminster road to see his friends Thomas Davis, of Longleat, and the Rev. Benjamin Richardson, then living at Woolverton. It has often been pointed out that the 1799 list, like the present one, omits all the upper part of the Jurassic together with the Lower Greensand, the reason being that the Gault rests directly on Oxford Clay at the only place (near the Black Dog Inn, south of Standerwick) where its outcrop crosses the Bath–Warminster road, and the exposures in the vicinity were insufficient to enable Smith to discriminate between the two clay formations. The Gault overstep is well seen at the present time in abandoned workings for Westbury Iron Ore near Bremeridge Farm, between Dilton Marsh and Penleigh, as demonstrated by Mr. G. A. Kellaway to the International Geological Congress party who visited the area recently. At the eastern end of these workings the Gault rests on Kimmeridge Clay, which itself overlies the iron ore, of Upper Corallian age. A little further to the west the Gault rests directly on the iron ore, and at the western end of the workings the ore has itself been cut out by the unconformity, and the Gault rests on Lower Calcareous Grit. Further west there is no trace at all of Corallian rocks. No doubt had the Westbury Iron Ore been worked in Smith's time he would have made a détour from his customary route early in his investigations to study its geological position ; this ore was, however, first worked in 1856.

As events were to prove, Smith's 1799 list of formations was somewhat premature. From that year onwards he was no longer tied to his canal work and had many more opportunities to explore the countryside around Bath and to travel to other parts of England. Such formations as the Bradford Clay, the Cornbrash, the Kellaways Rock, and the " Clunch " [Oxford] Clay were soon discovered and assigned to their correct stratigraphical positions. The Corallian rocks and Kimmeridge Clay of western Wiltshire and the Lower Greensand of Seend also became known to him, although it was not until the earlier copies of his great map of 1815 had been printed and distributed that the succession of the Upper Jurassic and Lower Cretaceous formations was correctly unravelled.

Classification and Phylogeny of the Tetrapods

By Baron Friedrich von Huene (Tübingen)

(PLATE X)

Abstract

Primary divisions of the lower tetrapods are believed to be expressed in the structure of the vertebrae, which represent an earlier formation embryologically than the skull. On this and other grounds the Urodeles are referred to an isolated group, the Urodelomorpha. Already in the embolomerous forms of the Carboniferous is seen the cleavage into Loxembolomeri (Batrachomorpha) and Anthrembolomeri; from the Anthrembolomeri again are derived the Diadectomorphs (Reptiliomorpha) and the Captorhinomorphs, the latter the ancestors of the Theromorphs (including Mammalia), the Archosauromorphs and the Neosauromorphs. From Triassic times onwards active evolution and the production of new types becomes progressively restricted, with the principal exception of the several Theromorph lines by which it is transmitted to the Mammalia and finally Man.

In former times animals were classified according to their mode of life and external appearance; more recently, especially since Linné, one attempts to express in the system so far as possible their anatomical relationships. This is primarily the task of the zoologists, whom palaeontologists have to follow. But among the lower tetrapods the number and variety of fossil forms so greatly exceeds that of living forms that palaeontology must itself supply a convincing expression of their relations. About a hundred years ago Richard Owen opened the way that others have followed, and five decades have passed since the fundamental work of Zittel's *Handbook* and the *Textbook*, which has appeared in several languages but few editions. One of the most modern of the numerous later attempts is Romer's *Vertebrate Paleontology*, where special attention is paid to phylogenetic relations. In the same direction, the writer intends to demonstrate some specially significant aspects of tetrapod classification.

Some basic points of phylogeny are reflected in the earliest individual development. The first to be formed is not the skull but the dorsal nerve cord, and the notochord, with supports surrounding both of them. Only subsequent to the formation of the nerve cord is the brain formed, with its protecting organs. Therefore, the writer assumes that the primary divisions of the tetrapods will be reflected in the basic structure of the vertebrae. In this matter, Gadow (1896) showed the way; through him we know that embryologically each vertebra begins as two neural arches and two chordal arches. The oral one of the latter arches, the basiventral, ossifies as the intercentrum and, in the tail, the chevron grows out from it. The caudal chordal arch, the interventral, becomes the pleurocentrum of the definitive vertebra. This

allows the possibility of recognizing from which of the two chordal arches the definitive ossified vertebral centrum has resulted when (as commonly occurs) there is but a single bone. If the haemal arch grows out of the ossified vertebral body, then the latter is the intercentrum (basiventral); but if there are special chevrons between the vertebrae in the tail, then the centrum is a pleurocentrum (interventral).

Considering the fossil lower tetrapods, it is found that in all Urodeles the vertebral body and chevron in the tail form a single piece, but in all reptiles the vertebral body and chevron are two pieces. It is, therefore, inconceivable that, for instance, a Permian Labyrinthodont could be descended from a Carboniferous Urodele. It might appear unnecessary to refer to such general points, but the same principle is true also of younger phyletic branches such as the rhachitomous and gastrocentral groups.

In two groups both of the chordal arches play an almost equally important part in individual development. In one of these groups both of the arches develop quite equally during Carboniferous times and the vertebra becomes embolomerous. In the other group the caudal arch ossifies very little later than the oral one already in Carboniferous times and the vertebra becomes rhachitomous; this tendency increases throughout Permian times, so that by the Upper Trias the basiventral alone ossifies without leaving any space for an ossified interventral (Stereospondyli). In the first-named group the reverse tendency operates, for to the embolomerous Anthracosaurs (Anthrembolomeri) the Seymouriamorphs are closely related, and here the basiventral ossifies a little later than the interventral arch, and the pleurocentrum becomes the essential vertebral body (gastrocentral vertebrae). This is still more the case in all other reptiles, and the intercentrum only appears as a minute bone in the presacral region, or is even unossified. So we see in the development of the bony vertebra the tendency to reduce the double chordal arch to a single one. The significance of this lies in the fact that delay in the ossification occurs either in the oral or in the chordal arch. This is the definitive fate for all later descendants. It is, therefore, unthinkable that any direct relationship between these two main branches could occur at any later time. The original cleavage must have occurred at some very early date (? Upper Devonian) as a differentiation of these tendencies while their actual appearance was still unchanged.

Regarding the first of these divisions, Jarvik (1942) has demonstrated that the Urodeles, on the one hand, and the Stegocephalia, on the other, come from two different branches of Upper Devonian Crossopterygia; according to his detailed investigations the Urodeles from the Porolepiformes and the Stegocephalia (and also the reptiles) from the Osteolepiformes. The Urodeles possess pseudocentral

vertebrae, a structure without parallel in other tetrapods. Therefore the Urodeles are to be considered as quite isolated descendants of the Crossopterygians, the Urodelomorphs. All other tetrapods, descended from osteolepiform Crossopterygians, might be called Eutetrapoda. Watson (1940) and Jarvik have shown that the Anura are derivable from early Labyrinthodonts. In the Anura, the circumchordal ossification in both the chordal arches is so much retarded that the united neural arches have time to grow ventrally and even surround the notochord. This produces the notocentral structure of the Anuran vertebra. The Upper Devonian Ichthyostegalia apparently form an early side-branch of the Stegocephalia (Loxembolomeri) in which the long interparietals and tabulars of the Crossopterygians are already shortened to half their size ; and this is the origin of the neck.

The second division, also beginning embolomerous with the Carboniferous Anthracosaurs (Anthrembolomeri), differs in several points of skull morphology. They have no rostral (internasal) bone ; the septomaxillary at first does not appear externally in the skull (in Urodeles it does not exist at all but is replaced by an anatomically different bone, the nariale) ; there is usually an intertemporal at first, which is absent in the Loxommids (with one exception) ; the medulla oblongata and the neurocranium are much shortened ; and the interparietal is always narrower than the parietal, so that the tabular is in contact with the parietal. In the Stegocephalia, the interparietal is always broader than the parietal. The parasphenoid does not embrace the otic capsule to any greater extent than it does in the Stegocephalians, and the inner ear is bounded by the opisthotic and prootic. The stapes goes from the fenestra ovalis to the quadrate and not to the otic notch of the skull roof as in the Stegocephalia. The long vomer is relatively narrow and borders the median side of the palatal nostril, while in the Stegocephalia it is relatively broad, pushing the choanae further apart. In the older representatives of this group the septomaxillary does not appear on the exterior of the skull.

The first-mentioned division constitutes the Batrachomorpha, the second division the Reptiliomorpha (Plate X). Originally the skull in both these divisions was anapsid. From Lower Carboniferous times, both groups run parallel to each other, and in several respects the differences between them increase with the passage of time. The Urodeles remain throughout their life in a larval condition in respect of exterior gills ; the Batrachomorpha pass through such a larval stage during some part of their life ; while only the most primitive orders (Anthrembolomeri and Seymouriamorpha) of the remaining groups pass through a short larval stage in youth.

The Reptiliomorpha are represented in the Lower Carboniferous by the Anthrembolomeri and their last representatives (*Archeria*, etc.)

reach the Lower Permian. The date of the real beginning of the later branches (orders) cannot be determined with any precision as we have only a limited number of sedimentary basins where remains of these animals occur. The Seymouriamorpha are known essentially from the Lower Permian ; the post-parietal part of their skull is much shortened. Amongst them are also semiaquatic forms with flattened skulls, such as *Phaierpeton* and *Kotlassia* ; another form, *Lanthanosuchus*, even has an opening in the temporal region. A primitive order are the Microsaurs, many of which are adapted to aquatic or semi-aquatic life. The post-parietal portion of the skull is shortened in most of them, so much so that the tabular row in some of them is wholly or partly pushed to the occipital wall ; but in the terrestrial forms, such as *Pantylus*, these elements occupy a larger space. The large size of the supratemporal is still characteristic of them, but the intertemporal has already disappeared. There is no longer an otic notch in the roof of the skull. The brain capsule is shortened and in the palate occurs a moderate-sized interpterygoid opening.

Another very primitive order, much obscured by extreme adaptation to a marine habitat and not known before the Lower Trias, is the Ichthyosauria. Some time ago, I considered that these were derived directly from the Anthrembolomeri, but I am now inclined to regard them as descended from some unknown semi-aquatic ancestors which might stand a little higher than the Seymouriamorphs. The middle ear of the Ichthyosaurs is organized as in Microsaurs, Diadectomorphs, and Seymouriamorphs. Their most primitive representatives are still nearly anapsid (*Mixosaurus*). The temporal opening, originating in connection with the development of a rostrum, is situated between parietal, prefrontal, and supratemporal ; I have called it *metapsid*, as distinct from the *synapsid* temporal opening between parietal, postorbital, and squamosal in the Theromorphs. Like all higher Reptiliomorphs, the Ichthyosaurs possess a single coracoid separate from the scapula ; but all Batrachomorphs have a fused scapulo-coracoid ; only the most primitive Reptiliomorphs, the Anthracosaurs, retain this latter form, and originally the Theromorphs have two coracoids.

The Diadectomorphs are typical terrestrial Reptiliomorphs. Their characters are sufficiently well-known through the recent work of Olson (1947) ; they have an otic notch, a tabular row, and even an intertemporal in the roof of the skull.

The Procolophonia and the Pareiasauria must have originated from the Diadectomorphs in the Permian, as also the Chelonia. These orders show different specializations ; only the Chelonia survive, thanks to the protection afforded by their carapace. Carnivores probably destroyed the other primitive orders.

The Captorhinomorphs are a parallel branch to the Diadectomorphs. They early lose the last vestige of an otic notch and the tabular row migrates to the otic wall. The supratemporal, too, is about to disappear. In a few of their late representatives a vestigial synapsid temporal opening appears (*Milleretta, Millerosaurus*). It is here that the Pelycosaurs take their origin in Upper Carboniferous time. Early sphenacodonts (Pelycosaurs) form the root of the Therapsids, and at the same time *Araeoscelis* is the beginning of the Protorosaurs. From another point in the primitive Captorhinomorphs, the Younginids (with two temporal openings) stand out as a beginning of the Thecodonts with their later Mesozoic descendants and, parallel to the Thecodonts, the Rhynchocephalia. Finally, the Squamata probably also arose from the Captorhinomorphs, through *Broomia* and *Prolacerta*.

The Theromorphs, in contrast to the Reptiliomorphs, are characterized by a *synapsid* temporal opening and the tabular row with few primitive exceptions has been pushed on to the occipital wall. In the post-cranial skeleton the Theromorphs have two coracoidal elements, which become united in the Triassic. A compact, independent aquatic parallel to the Pelycosaurs is the geographically restricted Lower Permian group of the Mesosaurs.

Pelycosaurs have been exhaustively treated by Romer and Price (1940) and the derivation of the Therapsids from early Sphenacodonts has been dealt with by the same authors. Somewhere near the root of the Therapsids in the Lower Permian also, the Placodonts and the Sauropterygians may be supposed to have diverged, though they are unknown before the beginning of the Trias.

In Upper Triassic and Lower Jurassic occurs the transition from Therapsids to Mammalia. According to Olson (1944), the oldest mammals in several classes must be looked on as a continuation of several distinct lines of Therapsids. On this view, which was forecast by Broom, the unity of the Therapsida does not end with the extinction of the Ictidosaurs, and the unity of the mammals does not begin with the first " mammals " as something absolutely new ; but rather the flow of families, lines, and (in later times) orders is advancing from Triassic into Jurassic and later periods. If the mammals had arisen from one single point in Therapsid stock (as, for instance, the Ictidosaurs), as was believed until recently, the conception would be quite different—the sudden birth of a new class. But this does not now seem to be the case. A more or less broad flow of lines passing (as it seems) from Triassic to Jurassic, with an earlier phase characterized by a more primitive stage in development of the ear and jaw and teeth (which is called " reptilian ") and a more advanced phase of these characters (called " mammalian ") is the present-day conception of the problem.

The Sauromorphs, which in Permian times originated from early Theromorphs, are characterized by two temporal openings, the upper one of which develops between the same bones as in the synapsid Pelycosaurs (postorbital squamosal and parietal) ; the lower one is bordered below by jugal and quadratojugal. Thus is produced the *diapsid* skull, first seen in the Eosuchia, leading on to the Thecodonts and all the great Mesozoic orders, the Saurischians, the Ornithischians, the Crocodilia, the Pterosaurs, and the birds, all of which originate in the Trias. A small and compact parallel-branch of the Thecodonts, the Rhynchocephalians, survive to the present day. They are rather an archaic order, and in contrast to the Thecodonts have retained the supratemporal. But Thecodonts and their descendants are all progressive.

A second division of the Sauromorphs, as mentioned above, comprises the Protorosauria and the Squamata. These possess a single temporal fenestra, bordered as in the synapsid Theromorphs, but having a tendency to loosen the quadrate by an increasing notch from the lower border between jugal and quadrate. This I named the *katapsid* skull. They constitute the Neosauromorpha, as distinct from the first division or Archosauromorphs.

In the view here expressed, the classification of the Tetrapods appears in its main features to be the result of several bifurcations. Firstly, from the osteolepiform Crossopterygians come the Embolomeres, which at the beginning of the Carboniferous are represented by the Loxembolomeri and the Anthrembolomeri. The former and their descendants constitute the Batrachomorpha ; the latter and their descendants begin with the Reptiliomorpha. In the latter again, the principal bifurcation is as between Diadectomorpha with their Reptiliomorph descendants and the Captorhinomorphs, from which come not only the Pelycosaurs and all other Theromorphs but also the Sauromorphs.

In Carboniferous and Lower Permian times the main branching continues and the Triassic is still a time of active evolution. But the further one proceeds in the Mesozoic, the weaker becomes the force of fresh production. Only the Squamata develop actively in the Cretaceous, when most others have reached a terminal stage of phyletic life, foreshadowing their end. Among reptiles, active evolution in relatively late times is restricted to the main lines of Theromorphs, especially transmitted through their mammalian descendants to a much later period, and finally to the origin of man and the human spirit.

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EXPLANATION OF PLATE

Phylogenetic tree illustrating the interrelations of the Tetrapods.

CORRESPONDENCE

EAST ANGLIAN DRIFTS

SIR,—Dr. Carruthers' recent letter in the *Geological Magazine* (1948, lxxxv, 367–8) is a stimulating challenge to the orthodox interpretation of the glacial deposits, but his conclusion that the boulder clays of East Anglia were laid down by a single composite ice-sheet does not fit the facts.

In the first place I understand that he considers that uncontorted sands below a boulder clay indicate deposition which accompanies the bottom melt of a stagnant ice-sheet. One place where this interpretation is wrong is at the well-known pit at Chillesford Church, where boulder clay rests on undisturbed Chillesford Beds which are certainly not connected with the bottom melt of any ice-sheet. This and other similar sections prove that it is possible for unconsolidated deposits to remain intact below an ice-sheet.

It is possible that some phenomena, especially within the Cromer Till Series, may exhibit the effects of bottom melt, fallen roof, and other characteristics of melting ice, but there is no reason to enlarge these interpretations into a theory which considers the extremely various boulder clays of East Anglia as overthrust layers in one ice-sheet. Dr. Carruthers admits disturbance of underlying beds by the " Cromer Tills of the Norfolk Coast " and by the " Lowestoft (Chalky-Jurassic) Till around Ipswich ", thus confirming some degree of readvance for at least two separate stages in East Anglia, and yet he proceeds to the contrary opinion that the whole East Anglian sequence is monoglacial. That these two tills belong to separate stages is proved by sections at Corton and elsewhere. Incidentally, as Boswell has shown, much of the folding in the Ipswich area was caused by the Gipping (" Upper Chalky ") Ice-sheet.

On the glacial evidence alone, therefore, there is no support for the theory that all the boulder clays of Norfolk and Suffolk belong to one glacial episode. The fossil evidence from certain horizons also disproves such an idea. The unique marine fauna of the Corton Beds, as proved long ago by Wood and Harmer, show that these deposits represent a change of facies and climate, as compared with the glacial beds above and below them ; and they cannot be explained as an included mass in a single ice-sheet, as they extend over an area of about 1,000 square miles, and in places attain a thickness of 80 feet. As regards Hoxne, Dr. Carruthers questions whether there has been a readvance of the ice in England after the freshwater beds of that site had been laid down. This problem has been debated for many decades, but it

seems to me that the gravel above the temperate deposits at Hoxne can be traced westward into Paterson's "Upper Boulder Clay" in the Breckland (Gipping Glaciation), and this geological evidence is supported by the finding of implements of Hoxne type below that boulder clay at West Stow, Elveden, and other places in the Breckland area.

As to the Hunstanton Boulder Clay, I would add that the old section (now closed down) at the Gasworks Pit at Hunstanton showed most clearly how the March Gravels had been ploughed into and partly incorporated by the overlying Hunstanton Boulder Clay, which is, according to Dr. Carruthers' theory, a proof of readvance. In general, it seems to me that there is abundant proof that the boulder clays of East Anglia were not formed from a single composite ice-sheet.

D. F. W. BADEN-POWELL.

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OXFORD.

6th May, 1949.

INDICATION OF GEOLOGICAL SITES

SIR,—Referring to Dr. Rastall's plea for greater accuracy in the use of place names by geologists (*Geol. Mag.*, 1949, lxxxvi, 110), and Mr. Percy Evans's, for full use of the National Grid in Great Britain (*Geol. Mag.*, 1948, lxxxv, 242), may I urge the use of geographical co-ordinates to indicate geological sites throughout the world? The advantages are so great that it is surprising to find this obvious method seldom adopted in the literature.

My experience in the Middle East, the Mediterranean area, French North Africa, and North-East Africa is that place names there are often of very limited value for the purpose. Many names that one learns in the field are not shown on any published map, and conversely, a common name may be found in more than one place on a given map. Neither Arab nor Somali, for example, is by nature imbued with that need for accuracy that is desirable in scientific work, and in their scantily populated countries location on the ground of some of their place names seems to a European, partly from the nature of the case, to be regrettably imprecise.

Grid references are excellent when the appropriate map is available, but obviously useless without it. On different maps of Somaliland, moreover, there are two quite separate grid systems, employed respectively by the War Office; and by East Africa Command during World War II. Such a case is probably not unique.

Geographical co-ordinates are most generally useful, though certain foreign maps printed with co-ordinates in grades, or with a prime meridian of Paris, Rome, Ferro, or other of the couple of dozen that are used in various parts of the world, may give rise to error unless these peculiarities are observed and allowed for. But the latitude and longitude (referred to Greenwich) of any point on the earth's surface can be easily plotted on nearly all maps, to as great an accuracy as required. General use of this method, which I have tried to apply for the past twenty years, would lead to greater accuracy and conciseness of indication, and would often save time and measureless exasperation to all who wish to pin-point a locality from the data of others.

W. A. MACFADYEN.

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8th May, 1949.

REVIEWS

PHYSICAL GEOLOGY. By C. R. LONGWELL, A. KNOPF, and R. F. FLINT. xvii + 602, with 365 text-figures. New York : John Wiley and Sons, Inc. London : Chapman and Hall, Ltd. Third edition, 1948. Price 30*s*.

The first and scond editions were published in 1932 and 1929, as a successor to Part I of *A Textbook of Geology*, by Pirsson. The present edition has again been revised and improved in text and illustrations. The principal addition is a new chapter 2, entitled " Method and Scope of Geologic Study ". This sets out to illustrate scientific method by the concepts of isostasy and geological time, so introducing these ideas at an early stage. The result is disappointing. The material in the first two chapters is good, but could be rearranged with advantage. However, this book continues to deserve commendation as one of the most reliable and well produced elementary texts.

W. B. H.

GEOLOGY AND SCENERY OF THE COUNTRYSIDE ROUND LEEDS AND BRADFORD. by H. C. VERSEY. pp. 94, with 19 figures. London : Murby and Co., 1948. 10*s*.

The frontispiece of this book shows the Leeds–Bradford district to include the outcrops of the Mountain Limestone in the upper parts of Airedale and Wharfedale, the Millstone Grit and Coal Measures stretching south to beyond the River Calder, and the Permo-Triassic limestones and sands which overlie these rocks in the east.

The work is introduced by a concise account of the science of geology, written with the minimum of technical terms, and with a wealth of local allusions. Chapters II to V deal respectively with the country occupied by the Mountain Limestone, the Millstone Grit, the Coal Measures, and the Magnesian Limestone, the first half of this last chapter being actually an account of the Carbo-Permian structures. Chapter VI (Rivers and Glaciers) is especially notable for its summary of the Pleistocene history of the region. The last chapter (Selected areas for field study) contains itineraries for thirteen excursions ; it concludes with Hints for Further Study, in which a few selected publications are recommended, a general bibliography being excluded, perhaps wisely in view of the very extensive literature on this area.

The book, which embodies the results of a great mass of research work, covers the ground with admirable balance and thoroughness. It is attractively illustrated with simple line-diagrams ; but among these certain of the cross-sections could with advantage have shown some indication of the vertical exaggeration, and the frontispiece would be improved by a scale. A few statements might be questioned, such as the reddening of underlying rocks by downward percolation of iron from the Permian (p. 54), and the alignment of coal workings to the " bord " (p. 44). *Carbonicola ovalis* (p. 43) should be *C. communis*, and there are more than four marine bands in the Coal Measures of the area.

Despite some slight trouble with the symbol for vertical strata on p. 13, and with numbering of geological maps on p. 88, the publishers have done their job well.

W. E.

DEEP BORING THROUGH ORDOVICIAN AND SILURIAN STRATA AT KINNEKULLE VESTERGOTLAND. By B. WAERN, P. THORSLUND, and G. HENNINGSMOEN. *Bull. Geol. Inst. Upsala*, xxxii, 1948, 337–474.

The Lower Palaeozoic section of Kinnekulle mountain has long been known to geologists. The sedimentary rocks are capped by a diabase sill which covers an area about half a mile in diameter, and is 27 m. (90 feet) thick ; it is to this hard capping that the relatively soft rocks owe their

preservation. In 1941 a borehole at Norra Skagen east of the summit proved the section from the Middle Ordovician to the top of the Lower Cambrian; in order to complete the section the Geological Institute of Upsala decided to put down another borehole "as a duty to Swedish geology". This was sited on the west side near the Kullatorp spring, and was put down by the Swedish Diamond Rock Drill Company to a depth of 88·56 m. (290 feet) in June, 1944; the diameter of the core was 70 mm. It started about 22·7 m. (75 feet) below the base of the sill, and penetrated the Llandoverian rocks as well as nearly 50 m. (164 feet) of Ordovician rocks nearly to the base of the Chasmops Series. The depth of the boring was designed to give a considerable overlap in the Ordovician between the Kullatorp and the Norra Skagen boreholes.

An account of it has now appeared. The lower part of the section from 63 m. to 88·56 m. (Chasmops Series) is described by Dr. Per Thorslund, the middle part from 3·515 m. to 63 m. (Tretaspis Series) by Mr. Gunnar Henningsmoen, and the upper part from the surface to 35·15 m. (referred to the Silurian) by Mr. Bertil Waern, who also planned and supervised the boring operations. The purpose of this note is to call attention to certain features of the section which are of particular interest to British geologists.

Chasmops Beds.—The *Chasmops* Series consists of grey mudstones and shales with a few beds of limestone mainly in the lower part; black shales with *Dicranograptus clingani* occur near the top. Numerous beds of bentonite, one of the about 1·8 m. thick, which occur between 66 m. and 76 m., are believed to represent fine volcanic dust from some distant area. The shelly fauna appears to contain many forms allied to those that make their appearance much later in the Ashgillian of England and Wales, such as *Phillipsinella* cf. *parabola*, *Trinodus*, *Remopleurides*, etc. Comparison with the borehole at Norra Skagen suggests that the base of the *Chasmops* beds was not reached at Kullatorp, and the two boreholes together indicate that the Ordovician sequence is about 112 m. (367 feet), excluding the *Dalmanitina* beds at the top (see below). In the lower part of the Kinnekulle section, *Nemagraptus gracilis* occurs, and it is suggested (p. 361) that the *Chasmops* Series is represented in the Caradoc or Lower Bala of Britain. It is tempting to correlate as the author does (p. 362) the bentonite beds which occur just below the black shales of the *Dicranograptus clingani* zone with "Caradocian periods of vulcanicity . . . for instance Snowdon and Llanwrtyd". The Snowdonian rocks occupy a closely corresponding position, but the Llanwrtyd rocks are probably older.

Tretaspis Beds.—The black shales (1 m.) with *D. clingani* are overlain by 12 cm. of a dark grey, slightly argillaceous and glauconitic limestone, which near the top is phosphatic and pyritic. This bed is overlain by black shales (2 m.) with *Climacograptus styloideus* which correspond with the *Pleurograptus linearis* zone in Britain. The basal part of the shale contains a shelly fauna which is quite different from that of the *Chasmops* beds below. The underlying limestone contains in its lower part *Tretaspis ceriodes*, but the boundary between the *Tretaspis* and *Chasmops* beds is drawn at a somewhat higher level and below a layer 15 cm. thick of dark marlstone containing scattered grains of glauconite. It is interesting to note that phosphatic beds occur in Wales in several places (Penygarnedd, etc.) immediately above black shales of the *D. clingani* zone.

The *Tretaspis* beds are mainly mudstones and shales, with one bed of a peculiarly veined limestone (Masur limestone) 1·2 m., which yielded no recognizable fossils. The mudstones are brownish-red with a few thin bands of green; two narrow bands of bentonite were noted in the upper part. The uppermost beds (2·65 m.) are described as the Grey or Top Sandstone, which is separated from the overlying *Dalmanitina* beds by a sharp break; from the lower half of this sandstone *Dalmanitina mucronata* is recorded. It is interesting to note that *Tretaspis seticornis seticornis* and *T. granulata bucklandi* occur in the same order as they apparently do in Britain.

A curious speckled shale occurs near the junction of grey mudstones and

black shales and as noted (p. 384) a speckled zone is found at the base of the *Phillipsinella parabola* beds in N. Wales. This curious rock type seems to resemble the " mottled beds " which occur at various horizons in the Ordovician and Silurian mudstones of Wales, viz. base of the Ashgillian (Berwyn; Sholeshook and Crymmych, Pembrokeshire); higher in the Ashgillian (Abercwmeiddaw beds); base of the Llandoverian (*Glypto. persculptus* beds); base of Middle Llandoverian (*Meso. magnus* beds); top of Llandoverian (*Mono. crenulatus* beds). They appear in all cases to accompany a change of physical conditions in the area of deposition. There may be more than one kind of mottling—one due to stirring up of black mud during the deposition of grey muds and the other possibly due to organic agencies.

Silurian.—In the rocks down to a level of 35·15 m. (115 feet) which are assigned to the Silurian three series are recognized in ascending order, viz. the *Dalmanitina* beds, the *Rastrites* beds, and the *Retiolites* beds. The main part of this section consists of shales and mudstones, but limestones were met at certain horizons. The black shales usually yielded graptolites; the mudstones, which are lighter coloured, and some of the limestones contain a shelly fauna. That of the mudstones consists mainly of small specimens and does not represent a fully developed shelly facies.

The Silurian facies in its small thickness and suggestion of several breaks in sedimentation, presents resemblances to the developments of the Llandoverian rocks of the Lake District and the Austwick area, but the graptolitic beds can also be compared closely with those of Central Wales. In fact, the lithology of the Silurian rocks suggests comparison during the Llandovarian with the English and Welsh part of the Lower Palaeozoic geosyncline rather than with the Scottish part.

The Ordovician-Silurian Boundary is drawn at the base of the *Dalmanitina* Beds at a depth of 35·15 metres. There is an obvious hiatus at this level between them and the underlying beds as shown by the sharp contact and the abundant angular chips of shale in the lowest limestones of the *Dalmanitina* beds. Unfortunately there is some uncertainty regarding the age of the sandy beds (2·65 m.) called the Grey or Top Sandstone, which intervenes between the *Tretaspis* Series and the *Dalmanitina* Beds. There " is no sharp lithological boundary " between the sandstone and the *Tretaspis* mudstones below (p. 427), and although the sandstone contains *Dalmanitina mucronata*, which is the characteristic fossil on the *Dalmanitina* Series, the sharp break at its top decided the authors to draw the Ordovician-Silurian boundary at that level. *D. mucronata* has been found in the Ordovician *Tretaspis* beds elsewhere in Sweden. It is more in accord with British experience to assign beds with *D. mucronata* to the Ordovician.

The *Dalmanitina* beds are 2·38 m. (7·8 feet) thick, and are divisible into three parts; the basal portion about 1 m. in thickness consists of crystalline, richly fossiliferous limestone with thin, sandy, and marly beds towards the top. The shale chips which are abundant in the bottom part, extend up to about 10 cm. The middle portion consists of fine sandy calcareous mudstone alternating with grey fine-grained sandy limestone; this is a little more than 1 metre and passes up into ·3 m. of a grey fine-grained calcareous sandstone and siltstone. At the top " the calcareous sandstone is yellowish grey, rusty, and weathered, and delimited from the overlying beds by an uneven denudation surface " (p. 346). Fossils occur in the uppermost portion only of this sandstone.

There is an obvious hiatus at the top of the *Dalmanitina* beds also, and special interest therefore attaches to this contact and to the age and lithological character of the lowest portion of the succeeding *Rastrites* beds. The shales for 50 cm. above this contact at 32·76 m. consists of fine bedded dark mudstones with some lighter layers and a concentration of pyrite quite near, but not at the base. The lowest 7 mm. of this mudstone " is mixed with washed-up debris from the sub-stratum; it is yellowish-grey with numerous rusty spots ". This description and that of the top of the

sandstone of the *Dalmanitina* beds clearly indicates that the lithological break between the *Rastrites* and *Dalmanitina* beds is complete, and where this happens it is impossible to judge from the appearance at the contact of the magnitude of the break or to forecast into what degree of unconformity it may develop in other areas. The concentration of pyrite associated with rusty washed-up debris is a familiar phenomenon near the base of the Silurian *Glyptograptus persculptus* zone) in Central Wales. At Kinnekulle, *G. persculptus* was not found, but some of the *Climacograpti* that are associated with it in Wales and pass up from that zone into the overlying zone of *Akidograptus acuminatus* are described. The lithology of the lowest *Rastrites* beds also compares rather with the basal part of the *A. acuminatus* zone than with that of the *G. persculptus* zone. It is probable for these reasons that the lowest beds of the full Silurian graptolite succession of Britain is missing at Kinnekulle above the hiatus. This may be compared with the succession in Ashgill quarry in the Lake District, where the lowest Silurian consist of beds above the *A. acuminatus* zone which rest sharply upon Ashgill Shales ; in many parts of that area the *A. acuminatus* zone is absent. I am of the opinion, therefore, that in comparison with the British sections the Ordovician-Silurian boundary should be drawn between the *Rastrites* beds and the *Dalmanitina* beds at a level 32·76 m. in the borehole. Difficulties have been experienced in determining the relations between the *Dalmanitina* beds and the *Rastrites* beds in various parts of Sweden. " The upper boundary of the *Dalmanitina* beds has not been definitely fixed. Graptolite shale belonging to various zones of the *Rastrites* beds usually form the upper boundary " (p. 459). It is partly for this reason that the opinion is held by Swedish geologists that the shelly facies represented by the *Dalmanitina* beds replaces laterally various horizons of the graptolitic shales. It would appear, however, in view of the clearly defined haitus in the Kinnekulle section that another interpretation is possible which would more satisfactorily account for the varying relationships observed between the *Rastrites* shales and the *Dalmanitin* beds in different parts of Sweden.

Only a few of the features of interest in the remainder of the Silurian section are mentioned. Between the Middle Llandoverian zone of *Monograptus convolutus* and the Lower Llandoverian shales at some distance below them, intervene about 1 metre of unfossiliferous limestones, but due to core losses of up to 50 per cent little information of their exact relationships to the beds above and below could be got. It is evident, however, that there is a considerable gap in the faunal succession at this level. There is no trace of the zone of *Monograptus triangulatus* with its various bands ; and it is almost certain that the zone of *Monograptus cyphus* is also missing, with possibly also some of the underlying zone of *M. acinaces*. A part of that zone seems to be represented by *M. incommodus*, and the zone of *M. atavus* is indicated by *Dimorphograptus extenuatus*. In view of the careful examination which was made of the *Climacograptus* species in the borehole, it is remarkable that the well-known and widely distributed *C. törnquisti* was not found. Although this species is most abundant in the *M. cyphus* and *M. triangulatus* zones it occurs also in the *M. acinaces* zone. Its absence at Kinnekulle probably confirms the magnitude of the break between the *M. convolutus* zone and the shales below. The Upper Llandoverian seems to contain a complete sequence of the zones from *M. turriculatus* to *M. crenulatus*, the British zone of *M. crispus* being obviously represented by *M. discus*. There is no evidence that the highest *Retiolites* beds reach to the base of the Wenlock. An interesting feature of the Upper Llandoverian is the occurrence of several thin bands of what is believed to be bentonite. This prompts a comparison with those recorded in several areas in the Upper Llandovery of Wales and the Welsh borders.

The University of Upsala and the Geological Institute are to be congratulated upon their enterprise in taking active and obviously highly successful steps to elucidate further the famous Lower Palaeozoic sections of Sweden. I wish it were possible to infect British Universities with their enthusiasm.

O T. J.

GEOLOGICAL MAGAZINE

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The Yorkshire Dogger

IV. ROSEDALE AND FARNDALE

By R. H. RASTALL and J. E. HEMINGWAY

ABSTRACT

The Lias-Oolite junction in Rosedale and Farndale is defined. The underlying Lias is folded into a pre-Oolite complex of shallow Caledonoid folds, wherein are preserved about 55 square miles of Yeovilian strata in the Cleveland region. The Rosedale East and Sheriff's Pit ironstones, now exhausted, are included on field evidence with the Yeovilian and not the Dogger. They occur in the troughs of two structural basins of limited extent in the fold complex, while other basins hold ironstones of no economic value. It is unlikely that the depositional basin of the Rosedale ironstones extended far beyond the present limits of the dale. Within Rosedale its distribution was materially reduced by erosion from the crests of minor pre-Dogger folds, pebbles now phosphatised derived from the crests occurring in the base of the Dogger.

A three-fold sub-division of the Dogger is recognized. The Glaisdale Oolite is here of little importance; the lenticular Rosedale Sandstone represents sand trapped in the continued down-warping over Rosedale in early Dogger times. The most widely spread rock group, the Blakey Series, includes the important Black Shales at its base. Marked facies variation is recognized in the sandy upper part, which includes the Ajalon facies, the Green Flag facies, etc., which were earlier incorrectly regarded as in chronological succession.

The Rosedale magnetite-oolite is regarded as a sedimentary deposit underlying the Dogger.

The petrography of the several beds of the Lias-Oolite junction is briefly described.

THE fertile valleys of Rosedale and Farndale, draining south off the Cleveland dome, expose the Lias-Oolite junction at the break in slope controlled by the heather-covered Deltaic Series [1] of the moors above and the Lias of the valley sides and floors. In many respects these exposures mirror those of the dales in the northern flank of the Cleveland dome already described (Rastall and Hemingway, 1943). Farndale reflects Westerdale and Danbydale in the relative simplicity of the Lias–Oolite junction, whereas Rosedale even exceeds the complexity of the Fryups.

Earlier descriptions of the Dogger of this region are few. In view of

[1] For the revised terminology of the Middle Jurassic of Yorkshire, see Hemingway, 1949.

the active exploitation of the ironstones at or near this horizon at the time of the survey it is notable that the Geological Survey sheet memoir (Fox-Strangways, Reid, and Barrow, 1885) is inadequate and at times incomprehensible. The later Survey report (Lamplugh in Lamplugh, Wedd, and Pringle, 1920) added little to this field account, but confused it by an indefinite and sometimes incorrect topography.[1] These official Survey records have recently been reprinted with slight additions (Anderson, 1942). Of the several field accounts of the magnetite-oolite, some of which are largely speculative, that by Marley is the most factual (Marley, 1869–70). More recently the petrography of some of these rocks has been described (Hallimond, 1925).

In the stratigraphical field Macmillan has demonstrated the presence of Yeovilian rocks in this area (Macmillan, 1932). In view of this work on the faunal subdivision of the Yeovilian, which is not yet complete, we have directed our attention mainly to the overlying beds, as we have already indicated (Rastall and Hemingway, 1943, p. 209). Reference is made to the Yeovilian in so far as it provides a necessary introduction to the sedimentary conditions controlling Dogger deposition and also with reference to the age and petrology of the Rosedale East and other ironstones, hitherto regarded as of Dogger age. Although not concerned with the zoning of the Yeovilian, we have determined its upper limit, from which the Inferior Oolite has not previously been differentiated.

In an earlier paper (Rastall and Hemingway, 1943) we divided the Dogger of Upper Eskdale into three series, subdivided as follows :—

Ajalon Series . .	Black Oolite Ajalon Oolite and Sandstone Woodhead Scar Sandstone
Chamosite Series . .	Finkel House Group Green Flags Danby Group Black Shale
Glaisdale Oolite Series .	Glaisdale Oolite

This classification now requires modification. As is shown later the evidence in Rosedale suggests that the Green Flags of the Danby Group and the Woodhead Scar Sandstone are only facies variants of the main Dogger sandstone, here named for convenience the Blakey Series. The terms will therefore be used only in facies terminology. The age of the coarser sandstones and the sandy oolites

[1] In the map, Fig. 7 on p. 29 of this memoir, Sheriff's Pit is displaced 1½ miles south-east of its real position.

of the Ajalon facies is here unproven. Field evidence is not conclusive, and future exposures may well prove them to be the coarsest facies of the Blakey Series, which opinion the writers now hold. The Finkel House group of oolites and chamositic rocks, known in Eskdale in but two small areas, is unrepresented in the southern dales. From the evidence in Rosedale these also may be facies variants of the Blakey Series. A green sandstone not found in Eskdale occurs widely in Rosedale below the Black Shales, where it is a valuable horizon marker; it may be named for convenience the Rosedale Sandstone. Only the Glaisdale Oolite is unrelated in Rosedale to the remainder of the Dogger sequence, but from evidence in Great Fryup it is placed below the Danby Group (Rastall and Hemingway, 1943).

The Dogger succession in Rosedale, which is also a revision of the succession of the dales to the north, is therefore as follows:—

Blakey Series . .	Black Oolite, Ajalon facies, Woodhead Scar facies, Green Flag facies, etc.
	Black Shales
Rosedale Sandstone .	A chamositic sandstone
Glaisdale Oolite .	

An outstanding feature of the rocks of the Lias-Oolite junction of Rosedale is the extensive development of oolitic ironstones which, with the exception of the magnetite-oolite, are all low grade. It is notable that this development is not confined to one horizon but occurs, though in varying degrees, in both the high Yeovilian and Inferior Oolite. It is the association and part superposition of two ferruginous rock groups at different horizons and under different geological controls, which has caused past confusion on the position of the Lias-Oolite junction in this region.

These ironstones have in the past been worked at the following mines:—

Rosedale East Mines, which have a worked-out area of about 550 acres, and which yielded chiefly a chamosite-oolite with 32·7 per cent metallic iron in the raw stone and 45·6 per cent iron in the calcined state (Fox-Strangways, etc., 1885). This latter figure is open to doubt, since it is identical with that of the iron content of calcined magnetic ironstone from these mines.

Rosedale Magnetite Mines, worked in medieval times, but which yielded over 3,000,000 tons of magnetite-oolite between 1857 and 1880 from two deposits each 5 to 6 acres in extent. The ironstone

contained 42·96 per cent metallic iron in the raw stone and 52 per cent in the calcined state.

Sheriff's Pit, a much smaller concern, working a chamosite-oolite with 36·6 per cent metallic iron in the raw stone (Fox-Strangways, etc., 1885).

Within Rosedale the multiplicity of abandoned ironstone workings and trial holes in the Dogger and subjacent beds increases rather than diminishes the difficulty of determining the nature of the Lias-Oolite junction. The adits are in all cases collapsed, and exposures in their vicinity obscured by debris. Unfortunately, this is particularly true of the Rosedale Magnetite Mines, where the collapse of the underground workings has formed a considerable syncline in the overlying beds. As a result the magnetite-oolite is nowhere exposed, and its field relations cannot now be directly determined.

Mention may also be made of the many landslips, some exceeding half a mile in length, which festoon the sides of the dales and too frequently hide critical horizons. Their presence did much to control nineteenth-century exploration for ironstone.

Apart from the unusual and in some cases unique developments of oolitic ironstone, the several members of the Yeovilian and the Dogger occur in Rosedale and Farndale, with little fundamental change in lithology from that described further north (Rastall and Hemingway, 1943). Further, the faunal content of the Dogger is no less sparse and no more diagnostic than in the northern outcrops. There is no need, therefore, to describe in detail the various members of the Lias-Oolite junction, but rather to consider immediately their inter-relation within the limits imposed by the lack of outcrops.

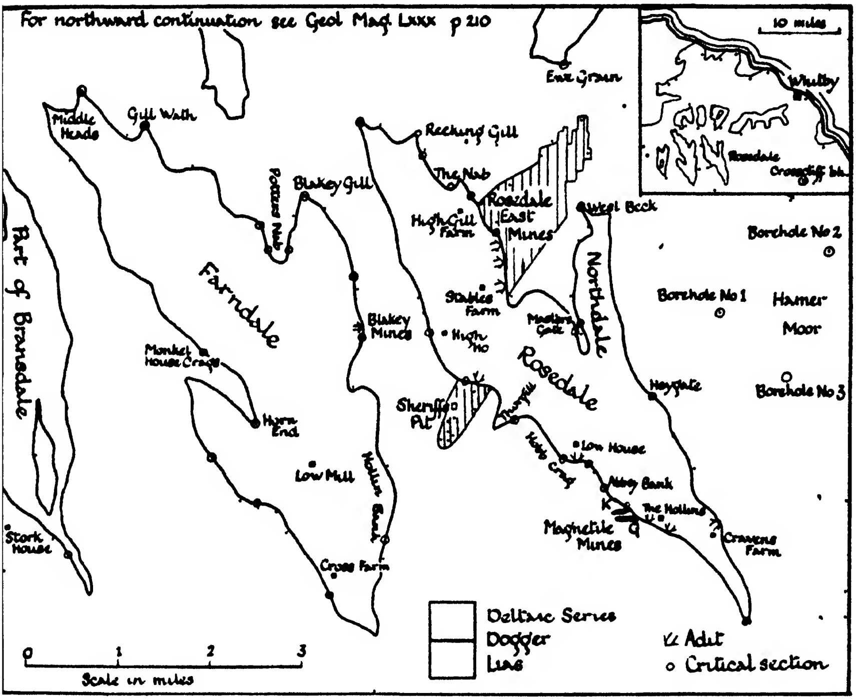
Field Relationships

Rosedale

At the north end of Rosedale the Lias-Oolite junction is typical of many of the western Cleveland valleys, and can be seen in Reeking Gill, in the shale gorge near the head of the River Seven, and in adjacent gullies. A generalized section at the dale head shows :—

	ft.	*in.*
Dogger—		
Blakey Series—		
Green Flags facies	4	0
Black Shale	6	0
Yeovilian—		
Siderite mudstone with chamosite ooliths, richly fossiliferous in places		9
Serpula Series—		
Serpula Sandstone	6	0
Striatulum clays	10	0

From the siderite mudstone a fauna including *Trigonia literata*, *Echinotis substriata* and species of *Cucullea* and *Gresslya* has been collected. These are long-range forms and of no diagnostic value, but the similarity of the lithological characters, field relations, and faunal assemblage of this bed to that at Double Dikes, Fryup (Rastall and Hemingway, 1943, p. 211), suggests its Yeovilian (*dispansum*) age. From the underlying Serpula Series, Macmillan has recorded ammonites



TEXT-FIG. 1.—Locality map of Rosedale, Farndale, and part of Bransdale, showing the underground extent of the ironstone mines (vertical ruling). Of the two magnetite mines (in black) K indicates Kitching's Deposit and G Garbutt's Deposit.

which place these beds in the *striatulum* zone (Macmillan, 1932), and which demonstrate a facies variation within this zone.

From Reeking Gill the Oolite-Lias junction may be traced southwards along the eastern side of the dale (Text-fig. 2). In this direction the thin Yeovilian siderite-mudstone thickens to some 6 feet of poor ironstones, pebbly throughout, while immediately below the Deltaic Series, the Green Flags facies pass into a more thickly bedded variant. Further, the Rosedale Sandstone appears between the Danby Group and the Yeovilian. Thus, in the disused railway cutting at the

Nab, 1,100 yards south-east of Reeking Gill, a complete section shows :—

	ft. in.	ft. in.
Lower Deltaic Series—		
Clay with thin coal		15 0
Soft feldspathic sandstone		5 0
Dogger—		
Blakey Series—		
Greenish sandstone in 9 in. beds		10 0
Green Flags facies		1 6
Black Shales		5 6
Scattered pebbles		
Rosedale Sandstone—		
Greenish sandstone		1 4
Yeovilian—		
Rosedale East Ironstone—		
Fossiliferous pebble bed		6
Dense siderite-mudstone with belemnite casts	1 6	
Oolitic siderite-mudstone	1 0	
Softer well bedded oolitic ironstone	3 1	6 4
Variably oolitic siderite-mudstones crowded with *Oxytoma inaequivalvis* (J. Sow.)	9	
Serpula Sandstone		5 0
Striatulum Clays		15 0

The next critical section lies 750 yards to the south-east and 300 yards E.S.E. of High Gill. Here the Rosedale Sandstone lies directly on the Serpula Sandstone and Rosedale East ironstone is cut out, though mine plans show that it was worked a short distance to the east. The Green Flag facies is replaced by a coarser variant approaching Woodhead Scar facies. The complete section is :—

	ft. in.
Dogger—	
Blakey Series—	
Brown sandstone in subsoil	—
Black silty shale	3 0
Rosedale Sandstone—	
Green sandstone with ooliths	3 0
Yeovilian—	
Serpula Series—	
Micaceous sandstone with fine vertical worm tubes near top : lower half crowded with massed serpulae	7 0
Row of purplish oolitic siderite-mudstone nodules	—
Softer silty sandstone	6 0
Harder serpula sandstone	1 0
Scree	

It is suggested that here the developing Rosedale East Ironstone was eroded from the crest of a rising N.E.–S.W. anticline at the end of Yeovilian times and the Dogger was subsequently laid unconformably across its truncated edges. In width this fold is only small, since to the south the ironstone again appears and soon attains sufficient thickness

to have been worked. But its control upon an ironstone once economically valuable is seen in the north-west boundary of the worked-out ironstone area which passes in an almost straight line through this outcrop (Text-fig. 1).

Behind Black Houses, 300 yards south-east of the previous section, the ironstone again appears between the Serpula and Rosedale Sandstones. This agrees with the mining records to the north-east, where the ironstone is " less than three feet thick and poor in quality " (Lamplugh, 1920, p. 30). South of this point for about 600 yards the collapsed adits and ruined buildings mark the site of Rosedale East Mines. Here the upper part of the Dogger may be traced almost continuously, as can the Serpula Series below, but the ironstone is usually hidden under scree. A typical section 300 yards east of Stables Farm shows :—

		ft.	*in.*
Lower Deltaic Series—			
Grey clays			
Dogger—			
Blakey Series—			
Khaki sandstone, oolitic and coarser near top, sandy and fine-grained below. Occasional lenses of siderite-mudstone up to 3 inches thick		10	0
Black shales with fine sandy lenses		4	10
Rosedale Sandstone—			
Greenish sandstone with ooliths		2	0
Scattered pebbles			
Yeovilian—			
Rosedale East Ironstone	*seen*	2	0
Hidden	about	6	0
Serpula Series—			
Typical sandstone with worm tubes and some silts		15	0

The upper part of the sandstone has yielded *Hudlestonia affinis* Seebach and *Phlyseogrammoceras* sp. confirming its *dispansum* age.

The ironstone has yielded a small fauna as follows, which should not be considered representative because of lack of exposures.

Gresslya abducta (Phillips)
Isocyprina sp. (conceivably " *Cardium* " *gibberulum* Phillips).
Ostrea (*Lopha*) sp.
Trigonia denticulata (Agassiz).
Trigonia spinulosa (Young and Bird).
" *Terebratula* " *trilineata* (Young and Bird).

No ammonites were found, nor have they previously been recorded from the ironstone.

In the central part of the mine the ironstone was generally 7 feet thick, from which it diminished in all directions (Lamplugh, 1920, p. 30). A maximum thickness of 14 feet was also claimed (Fox-Strangways, etc., 1885, p. 26). It is also recorded that " for a short distance there is a seam of magnetic stone about 14 inches thick, containing *Pecten demissus*, Phil. . . . It formed a lenticular mass in the

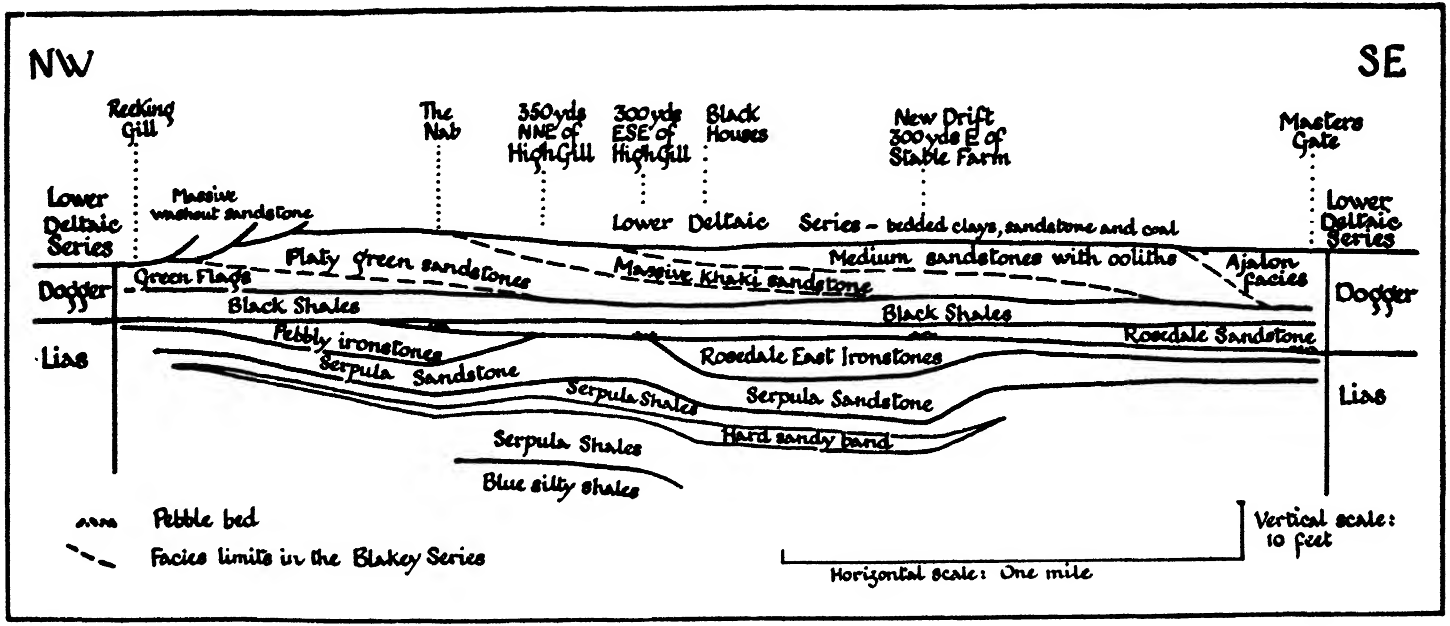
ordinary stone and showed a similar oolitic structure" (Fox-Strangways, etc., 1885). This rock is not exposed and no specimens are known.

Our measured section agrees closely with the oft-quoted "quarried face at Moor Hill, Rosedale East Mines" (Fox-Strangways, etc., 1885; Fox-Strangways, 1892, p. 170; Lamplugh, 1920, p. 30; Anderson, 1942, p. 30), a locality which has not been identified but which must be near here. In these published sections reference is made to the "Belemnite" of the ironstone miners, described as "a very poor and soft ironstone, full of casts of belemnites" (Fox-Strangways, etc., 1885). This bed apparently led to some confusion, for it was elsewhere analysed for iron (Lamplugh, 1920, p. 42), but it is clearly the Serpula Sandstone underlying the ironstone, a fine-grained sandstone feebly stained with limonite at outcrop and of no economic significance.

From the foregoing evidence it is claimed that the Rosedale East ironstone is not of Dogger (Inferior Oolite) age, as hitherto has been maintained (Fox-Strangways, etc., 1885; Lamplugh, 1920; Hallimond, 1925; Anderson, 1942), but is late Yeovilian. No direct faunal evidence for this is at present available. Field evidence shows, however, that this ironstone is a thicker and more oolitic representative of a widespread ironstone which in Danbydale to the north is of proved *dispansum* age (Rastall and Hemingway, 1943, p. 211). From the head of Rosedale this bed may be traced in successive exposures until it reaches a maximum at the mines. It would appear that the ironstone thickens in part by the addition of higher beds not represented to the north, but this cannot be proved. At the mines the ironstone is overlaid by a pebble bed or the pebbly base of the Dogger, which here as elsewhere marks the Lias-Oolite junction.

To the south-east of the mines the ironstone is not exposed for nearly a mile, but it is evident that it thins and deteriorates in this direction (Lamplugh, 1920, p. 30). Only the upper beds of the Dogger are exposed, usually deeply weathered khaki or deep red, ill-graded, pebbly sandstones of Ajalon aspect. At Master's Gate, near Bell Top, a complete succession shows the full effect of the changes, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Dark shales		
Dogger—		
Blakey Series—		
Ajalon facies : grading from a ferruginous sandstone near base to a fine oolite at top	10	0
Black shales, sandy at top	3	0
Rosedale sandstone—		
Greenish sandstone with ooliths and pebbly base	5	6



TEXT-FIG. 2.—Section along N.E. side of Rosedale through Rosedale East Mines, showing :—
(*a*) the Lias-Oolite unconformity, consequent upon pre-Dogger folding.
(*b*) the wedging Rosedale Sandstone.
(*c*) facies variation in the Blakey (Dogger) Series.

	ft.	*in.*
Yeovilian—		
Siderite-mudstone with chamosite ooliths, calcite chips, and worm tubes	1	6
Serpula Series—		
Massive serpula sandstone	3	6
Shaly sandstone with occasional siderite-mudstone nodules with chamosite-ooliths	6	0
Sandy shale . . . *seen*	6	0

Here the Rosedale East ironstone is represented by the much thinner and very low-grade siderite-mudstone. The Rosedale sandstone attains its maximum development. The Ajalon Oolite was worked for ironstone round Bell Top and Master's Gate in small opencasts, but the tonnage won was quite trivial compared with the Rosedale East ironstone.

The Ajalon facies may be traced up Northdale where, at the head, it is well exposed in West Beck, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Sandstone, flaggy and slumped	3	0
Shale	3	0
Coaly shale		6
Grey shale	10	0
Dogger—		
Blakey Series—		
Ajalon facies : grey chamosite-oolite with fine gravel-bed 4 feet from top	15	0
Rosedale Sandstone ?—		
Yellow sandstone	4	0
Yeovilian—		
Serpula Series—		
Fine-grained sandstone with belemnite casts and fossils in nests : harder beds feebly oolitic	3	0
Harder course of typical Serpula-bored sandstone	1	6
Alternating beds of purplish sandstone and shaly beds also oolitic	10	0
Sandy shales . . . *seen*	6	0

This section is similar to that at Yew Grain, Great Fryup, only 1½ miles to the north (Rastall and Hemingway, 1943, p. 219) except in the development of poor ironstones in the Yeovilian, which may be also seen in North Gill to the east, where they have yielded *Trigonia* sp.

On the east side of Rosedale exposures are few, because the southerly dip carries the Lias-Oolite junction below the level of cultivation. Yeovilian rocks cannot be traced south of Stone Bank Crag and in Heygate Bank at 750 feet O.D., only a greenish sandstone with ooliths, a variant of the Blakey Series, is exposed. The profound changes that must take place in the next 1½ miles are hidden, but their extent may be seen in a collapsed trial hole for ironstone 150 yards north of Craven's Farm, where the succession shows no resemblance to those already described. Only a few feet of deeply weathered and now limonitized ironstone, originally a sideritic mudstone with chamosite ooliths, may

be seen, with a basal pebble bed, resting on blue Whitbian shale. The ironstone yielded an abundance of long-range lamellibranchs, with occasional brachiopods and gastropods, as follows :—

Lamellibranchs :
- ? *Astarte elegans* J. Sow.
- *Camptonectes laminatus* (J. Sow) (= *lens* auct.).
- *Ceratomya bajociana* (d'Orb.).
- *Cucullea* sp. indet.
- *Gervillia tortuosa* (J. de C. Sow.).
- *Gresslya abducta* (Phillips).
- *Lima (Plagiostoma) castertonense* Cox.
- *Lopha* sp.
- *Modiolus cuneatus* J. Sow.
- *Modiolus plicatulus* J. Sow.
- *Pinna* sp.
- *Pleuromya* sp.
- *Protocardia ferruginea* Rollier (= *Cardium striatulum* Phil. *non* Sow.).
- *Trigonia spinulosa* (Young and Bird).
- *Velata abjecta* (Phillips).

Gastropod :
- *Procerithium muricatum* (J. de C. Sow.).

Brachiopod :
- "*Terebratula*" *trilineata* (Young and Bird).

No ammonites were found. The fauna resembles, but is not identical with, the more extensive assemblage from the Glaisdale Oolite (ironstone), 6 miles to the north (Macmillan, 1932, p. 127), where the relative abundance of the species is also different. At Glaisdale, "*Terebratula*" *trilineata* and *Homoeorhynchia cynocephala* are outstandingly abundant, whereas at the Craven's Farm tip the latter form is not found, and *Lima* (*Plagiostona*) *castertonense* and *Velata abjecta* are dominant. It may be noted that here the trial drift was cut in shales *below* the Dogger and was presumably made in the hope of finding a continuation of the magnetite-oolite, which occurs on the opposite side of the dale.

On the west side of Rosedale the character of the rocks of the Lias-Oolite junction usually bears so little relationship to those on the opposite side of the dale, less than a mile away, that they will again be described in some detail (Text-fig. 3). For two miles south of the dale head, landslips lie on the contact and only fragments of the Danby Series and the Serpula Beds may be found. A complete section is exposed by the waterfall 500 yards west of High House, as follows :—

	ft. in.	*ft. in.*
Dogger—		
Blakey Series—		
Greenish, platey sandstone in beds up to 12 inches thick		12 0
Green Flag facies passing down to		2 6
Black Shales		3 2
Rosedale Sandstone—		
Coarse greenish sandstone with oolith relics and casts of *Terebratula*		2 2
Pebble bed		

	ft.	*in.*	*ft.*	*in.*
Yeovilian—				
Serpula Series—				
Lilac-grey ironstone with vertical worm tubes and scattered ooliths. Casts of *Pecten* and belemnites	1	8		
Clay with chamosite ooliths	1	4		
Grey siderite mudstone		6	6	2
Greenish clay	1	2		
Green oolitic ironstone	1	6		
Typical Serpula Sandstone			1	10
Pale grey clay . . . *seen*			10	0

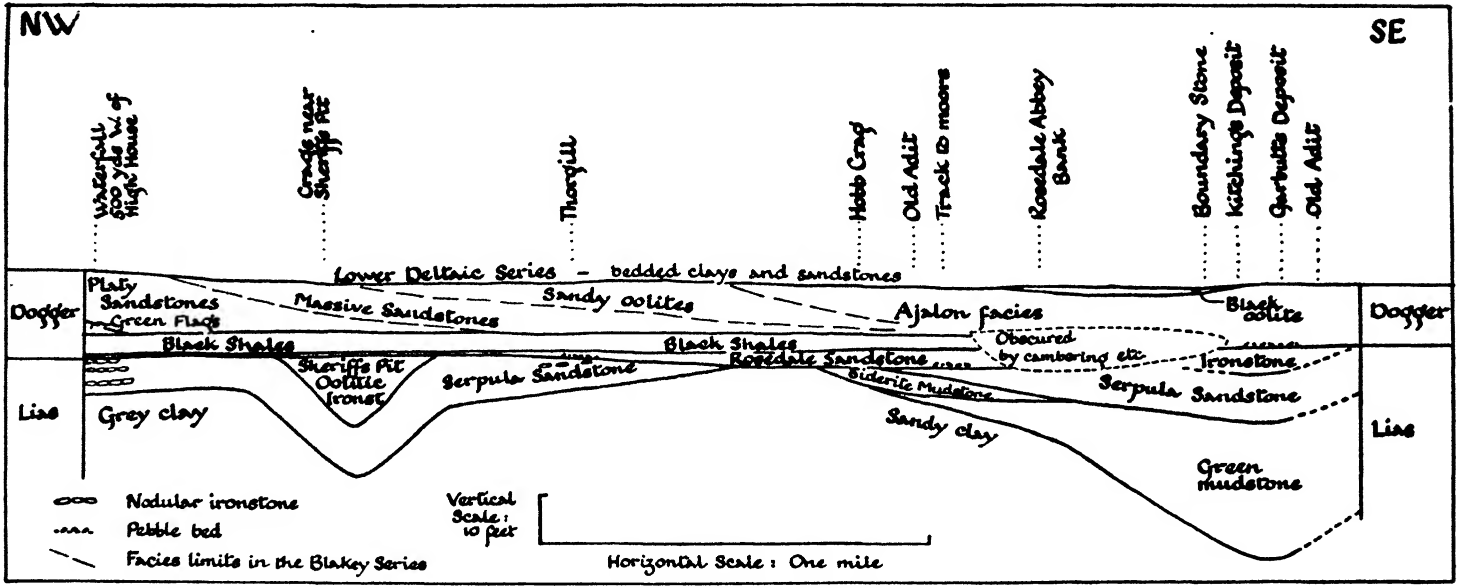
This exposure lies on the extrapolated south-east boundary of the exhausted area of the Rosedale East ironstone (Text-fig. 1). The poor ironstones and oolitic clays here present at the critical horizon represent, it is suggested, the feather edge of the original extent of the ironstone, which must have therefore extended about a mile south-west of its present outcrop. It may be said here that no trace of the Rosedale East ironstone has been found either on the west side of Rosedale, or in Farndale half a mile further south-west. Its form, after the pre-Dogger erosion, was most probably oval in plan, of which rather less than half was since eroded by the River Seven (Text-fig. 1).

Half a mile E.S.E. of the previous section the crags west of the old adits to Sheriff's Pit expose the following :—

	ft.	*in.*
Lower Deltaic Series—		
Massive feldspathic sandstone	20	0
Dogger—		
Blakey Series—		
Varying from a fine sandstone below to a greenish sandy oolite above	10	0
Black Shales	4	0
Yeovilian—		
Sheriff Pit Oolite—		
Green chamosite oolite, weathering brown	12	0
Serpula Series—		
Worm-bored sandstone . . . *seen*	2	0

From a locality near here, if not the same, Lamplugh recorded a similar section, but with double the thickness of shale (Lamplugh, 1920, p. 30). He also records that the ironstone, which he divided into four beds on a colour difference probably due only to weathering, rapidly thins out in all directions in the mine. He further states, rather remarkably, that the sandy upper bed of our Blakey Series, was worked for ironstone, though only at outcrop.

Again, there is no palaeontological evidence for the age of this ironstone. Its few fossils which occur crushed on occasional bedding planes are all of long range and therefore useless. Although the petrography is described later (p. 269) it may be said here that the Sheriff's Pit ironstone differs from that at Rosedale East in some of its lithological characters.



TEXT-FIG. 3.—Section through S.W. side of Rosedale showing :—
(*a*) two structural basins of pre-Dogger age, with Dogger resting unconformably across them.
(*b*) the lenticular Rosedale Sandstone.
(*c*) facies variation in the Blakey Series.

The magnetite oolite of Kitching's and Garbutt's Deposits is omitted from this section though the positions of their original outcrop are marked. On the exaggerated vertical scale of this diagram the magnetite-oolite deposits would extend as deep, narrow troughs from the base of the Dogger to a level below the base of the green mudstone.

In a steep moor-edge gully 400 yards south of Thorgill village and 1,000 yards south-east of Sheriff's Pit there is no ironstone. In view of its relative simplicity, in contrast to the succession both to the north-west and south-east, the section may be quoted.

	ft.	*in.*
Lower Deltaic Series—		
Massive sandstone	15	0
Dogger—		
Blakey Series—		
Fine sandstone near base passing up to coarser sandstone with ooliths	12	0
Black silty shales	3	6
Rosedale Sandstone—		
Greenish sandstone with ooliths	2	0
Pebble bed		
Yeovilian—		
Serpula Series—		
Soft, fine-grained, micaceous sandstone	3	0
Row of siderite-mudstone nodules	—	
Soft greenish-yellow sandstone	2	0
Typical Serpula sandstone	4	0
Serpula Shales	10	0

The three Dogger members may be traced south-west below Hobb Crag with little change except that the Ajalon facies coarsens in grade and the Rosedale sandstone becomes more oolitic. The pebble bed develops into a prominent shaly layer with well-rounded pebbles up to 3 inches long. Near this point begins a series of changes in the Yeovilian succession which extend south-west beyond the magnetite mines. Three hundred yards south-west of Low House the Dogger, with its basal pebble bed, rests on a flinty siderite-mudstone with occasional ooliths, while in a gully 270 yards further east these beds are separated by 30 inches of typical Serpula Sandstone. Here again then is evidence of minor pre-Dogger folding within the main tectonic basin within which the Yeovilian is preserved (Rastall and Hemingway, 1943, p. 213). Additions to the Yeovilian succession are also initiated near here, for in the gully section 200 yards south of Low House, a greenish mudstone which assumes great importance in the magnetite mines 1,200 yards to the south-west, first appears beneath the siderite-mudstone. These beds may best be seen in a crag by the side of an old track to the moors, 200 yards S.S.E. of Low House, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Poor coal with seat-earth	1	6
Sandstone	2	0
Shaly sandstone	2	0
Carbonaceous shale	2	6

	ft.	in.
Dogger—		
Blakey Series—		
Variable sandy oolite, grey when fresh, slightly current bedded	10	0
Black Shales, silty at top	3	0
Rosedale Sandstone—		
Greenish massive sandstone with ooliths, wood fragments, shale flakes and layers of shell debris	5	0
Prominent pebble bed		3
Yeovilian—		
Serpula Series—		
Serpula-bored sandstone, greenish and micaceous, with belemnite and pentacrinus casts	3	8
Oolitic siderite-mudstone passing to	2	6
Ferruginous mudstone, greenish when fresh and shattered by irregular joints	2	0
Soft grey sandy shale with vertical *Gresslya donaciformis*	6	0
Blue shale	20	0

In Rosedale Abbey Bank (Rosedale Chimney), half a mile south of Rosedale Abbey village, the Yeovilian is not fundamentally altered, though severe cambering has hidden the lower beds of the Dogger. Ajalon oolite, with a capping of Black Oolite is typically developed and dips steeply valleywards.

South of the road the Ajalon Oolite was tried for ironstone and in the old tramway 270 yards south of Woodend Villa the Dogger is exposed. Here, the Black Oolite may be seen dying away to the south and below it is a variable oolite of the Ajalon facies.

The Yeovilian beds are exposed on the flanks of those parts of the two magnetite-oolite deposits which were worked by opencast methods, a mile S.S.E. of Rosedale Abbey village. On the north-west wall of Kitching's deposit is exposed :—

		ft.	in.
Dogger—			
Ajalon facies : yellow, brown, and soft oolite	*seen*	2	0
Pebble bed in pasty mudstone matrix			2
Yeovilian—			
Serpula Series—			
Greenish micaceous chamosite-oolite		4	6
Green Serpula sandstone		10	0
Well-bedded shale	*seen*	1	6
Mainly green mudstone, in part hidden		20	0
Green mudstone with scattered pebbles broken by irregular joints	*seen*	8	6
Floor of old ironstone working			

Macmillan, who has recorded this section rather differently, has assigned the lowest bed to the *striatulum* zone and the remainder of the Yeovilian to the *dispansum* zone, though the upper 6 feet doubtfully so (Macmillan, 1932, pp. 129–130). The flanks of Garbutt's deposit immediately to the south show 12 feet of variable Ajalon facies and sandstone resting on 30 feet of Yeovilian beds, much of which is hidden.

This increase in thickness of that part of the Yeovilian from the greenish mudstone to the base of the Dogger from 8 feet in the gully 200 yards south of Low House, to at least 45 feet (Macmillan's estimate is 51 ft. 6 in.) on the flanks of the magnetite-oolite deposits is unique in north-east Yorkshire. It is brought about partly by synclinal folding before pre-Dogger peneplanation, but mainly by the development of beds not elsewhere represented, in particular the greenish mudstone. It is unfortunate that the Lias-Oolite junction is not exposed to the south-east until it reaches river-level 1½ miles away. Here, near Hartoft Bridge Farm, a sharply folded section shows about 20 feet of Dogger, grading up from a massive dark green oolitic ironstone to a grey sandstone with siderite lenses and resting upon blue-black Whitbian shales with *Meleagrinella sub-striata* (Munst). The Yeovilian is absent. In this distance there is hidden the entire south-east limb of this pre-Dogger syncline, which is also the south-east boundary of the Yeovilian rocks preserved in the main synclinorium (Text-fig. 4).

Farndale

Throughout Farndale the field relations of the Dogger-Lias junction are simple. Thus, in a small waterfall a quarter of a mile north of Blakey Mines is exposed the following :—

		ft.	*in.*
Lower Deltaic Series—			
Soft, well-bedded sandstone with soft jet		15	0
Dogger—			
Blakey Series—			
Massive greenish sandstone weathering spheroidally		6	0
Black silty shales		4	0
Yeovilian—			
Serpula Series—			
Siderite-mudstone			6
Blue argillaceous silt with worm tubes		12	0
Soft silty shales	*seen*	6	0

The massive greenish sandstone is not always present, and usually the Dogger is represented in Farndale only by the Green Flags facies resting on a few feet of black shales. These two beds have been found throughout Farndale from an unnamed gill 700 yards north of Middle Heads, at the north-west corner of the dale to the Daleside Road at the south end. Frequently, as at Gill Wath, the base of a Lower Deltaic washout cuts irregularly into the Green Flags, and may even locally remove them, as on the hillside 250 yards south of Cross Farm. A minor variation in these usually constant flags is at Hollin Bank, where a 2 in. bed of limonitic ironstone crowded with plant debris suggests a bog iron ore formed during a minor elevation which carried the locality above the usual shallow-water marine environment.

Only at Blakey Mines is there any variation in the normal succession.

Here 10 feet of deeply boxed and very variable sandy oolite (Ajalon facies) has been worked on a small scale for ironstone. It passes up into Black Oolite, and its sandy base rests on a full development of the Danby Group.

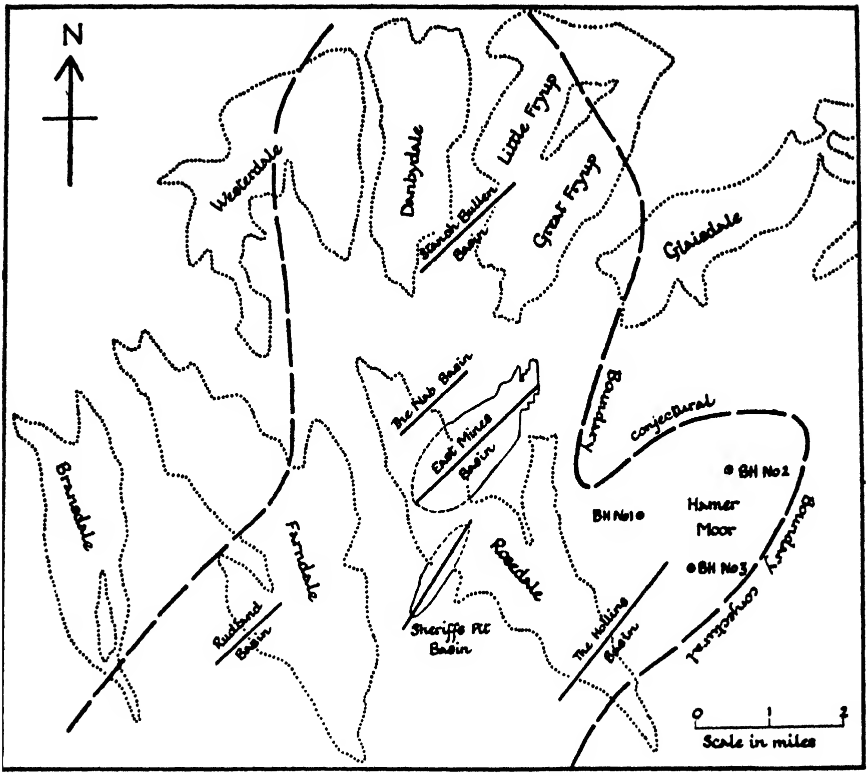
The massive Serpula Sandstone of *dispansum* age, so prominent near Rosedale East Mines, is not represented in Farndale except near Hollin Bank. Only silty clays, which elsewhere occur below the Serpula sandstone proper, are found, but they are confined to the east and south of the dale. Nor is the succession within these clays complete, since they frequently show one or more thin pebble beds, as in the gully 700 yards west of " Three Tuns " Inn and in the slip near Blakey Gill. When traced west, as at the head of Farndale, these grey and blue silty shales of *striatulum* age thin out, as at Potter's Nab. They are replaced, beneath the Black Shales of Inferior Oolite age, by blue-black shale of late Whitbian age, sometimes with a few inches of siderite mudstone at the junction, which has yielded *Nuculana*.

The Distribution of the Yeovilian

The belt of Yeovilian rocks, which in upper Eskdale and its tributaries is 4½ miles wide, continues south into Farndale, where its western limit, near Potter's Crag and Monket House Bank, can be traced with some accuracy, and into Rosedale, most of which lies within the belt. But below Stork House, at the south end of Bransdale, 18 inches of typical Serpula Clay below the Dogger indicates that here the edge of the belt swings further west (Text-fig. 4). Further, in each of the three Hamer Moor bore-holes sunk to the east of Rosedale to prove the Top Seam (i.e. the Dogger *s.l.*), several feet of " belemnite " or " belemnite ironstone " were recorded (Lamplugh, 1920, p. 43), proving a further extension of Yeovilian beds to the east. This Yeovilian outcrop pattern suggests folding of pre-Dogger age in a N.E.–S.W. direction, which is supported by the plan and orientation of the exhausted areas of the two ironstone mines of Rosedale East and Sheriff's Pit (Text-fig. 1). These are, from their ovate plan, neither ironstone-filled washouts nor, from the evidence at outcrop, belts of a ferruginous facies variation. All available evidence indicates that these ironstones are preserved in shallow basins of tectonic origin, elongated approximately N.E.–S.W.

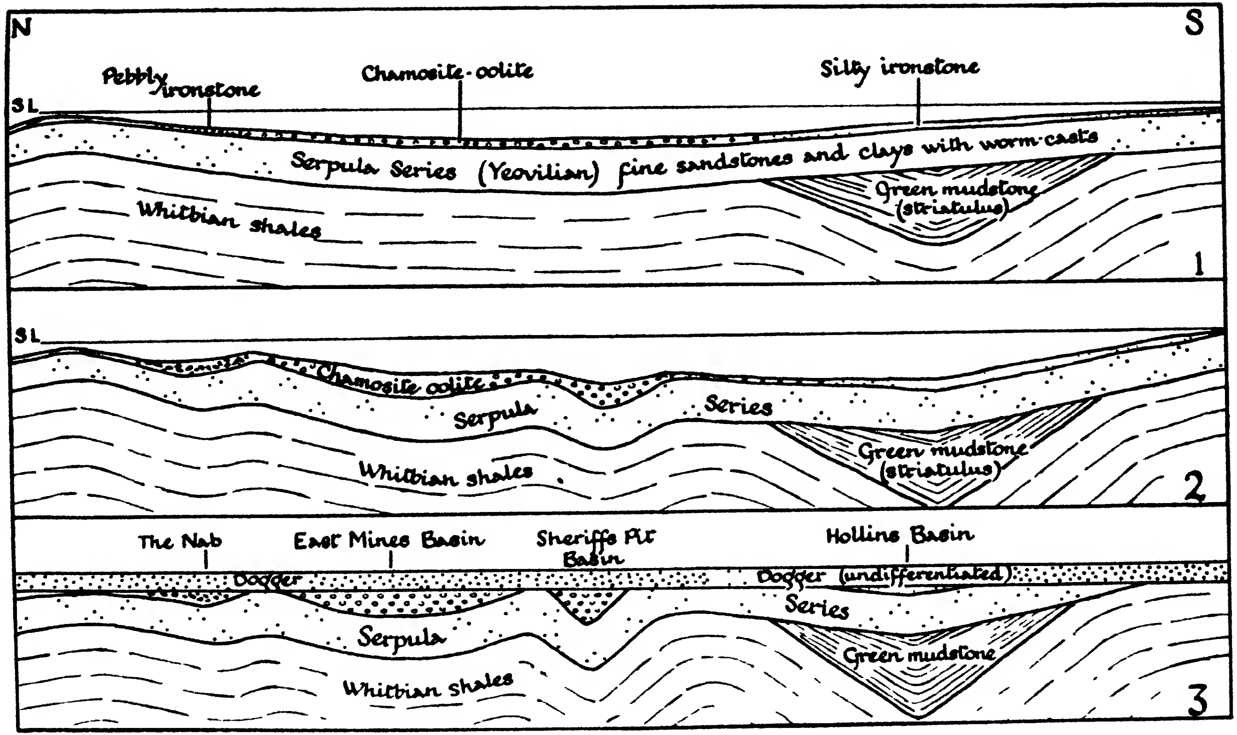
The age of the folding is undoubtedly pre-Dogger, as is shown by the unconformity at outcrop and the form of the worked areas. The several members of the Dogger sequence are unaffected by the folding, from which they are separated by a strong pebble-bed. Further, ironstone eroded from the crests of the elongated domes during the pre-Dogger planation contributed as pebbles, now part-phosphatized, to this bed both in the Rosedale area and also further afield (Rastall, 1905 ; Rastall and Hemingway, 1940, p. 272).

Several lines of evidence suggest that this folding may have been initiated during late Yeovilian times. Thus, the two ironstones at Rosedale East Mines and Sheriff's Pit, although similar in their essential constituents, differ in detail; for example, the relative proportions of siderite matrix and chamosite ooliths; the birefringence of



TEXT-FIG. 4.—Map showing the distribution of Yeovilian rocks (within the broken line) in the pre-Dogger structural basin. The black N.E.–S.W. lines indicate the major axes of smaller structural basins in the Yeovilian which together comprise the main basin. East Mines basin and Sheriff's Pit basin contained ironstones of past economic importance. The remaining basins hold impure low-grade ironstones of no value.

the chamosite; the distribution and abundance of the fossils. This suggests that the two ironstones were deposited in basins which, though not separate were developing individual characteristics. Further, in the Hollins Basin the development of 30 feet of silty chamosite mudstone *before* the Serpula sandstone of *dispansum* age, may indicate a long-continued downsinking of this area, with a consequent instability which gave rise to micro-slumping (p. 267).



TEXT-FIG. 5.—Diagrammatic N.–S. sections of Rosedale, illustrating the development of the Yeovilian ironstones and associated beds. Not to scale.

1. Deposition of Yeovilian ironstone with silty or pebbly margins within the Rosedale basin of sedimentation.
2. Development of late-Yeovilian folding dividing the main sedimentational basin into minor structural basins.
3. Dogger resting unconformably on Yeovilian and Whitbian.

Here also the oolitic ironstone at the top of the Yeovilian differs in detail from those at Rosedale East and Sheriff's Pit.

The Rosedale East basin is larger and shallower than that at Sheriff's Pit. The maximum thickness of ironstone at Rosedale East was claimed to be 14 feet (Fox-Strangways, etc., 1885, p. 26), though this is open to doubt. The maximum thickness of ironstone is, however, an indication of the amount of downfolding, and the boundaries of the worked area mark its thinning to 3 feet or slightly less. The Sheriff's Pit basin is more limited in area, with a maximum width of 600 yards of economically workable ironstone and a measured thickness at outcrop of 12 feet of ironstone (p. 212) which is probably not the maximum. Of the orientation of the Hollins Basin little can be said, since the ironstone here did not merit exploitation; the occurrence of Yeovilian under Hamer Moor, however, supports an elongation to the north-east, roughly parallel to that of the other basins. A fourth basin, smaller than the others, lies north-west of that at Rosedale East. It preserves only the developing edge of the Yeovilian ironstone as seen at the Nab (p. 206), which is thinner, less ferruginous, and more phosphatic than in the Rosedale East basin.

Southern Farndale shows the effect of this folding in a less striking manner. The south-westerly extension of the Sheriff's Pit axis controls the distribution of the Serpula Sandstone near Hollins Bank. More significantly the south-west swing of the Yeovilian boundary in this dale is controlled by a shallow basin with its axis near Garnet's Crag, West Gill. This, however, preserves only siderite-mudstones in its ill-exposed trough.

The N.E.–S.W. alignment of the pre-Dogger basins in this area further suggests that the distribution of the Yeovilian in the Fryups and Danby is not controlled by a simple pre-Dogger tectonic basin elongated north–south, as was originally suggested (Rastall and Hemingway, 1943, p. 213), but by a series of smaller basins each elongated approximately N.E.–S.W. and arranged in echelon from north to south. In one of these the thin Stanch Bullen ironstone of Great Fryup (p. 222) is preserved.

Of the distribution of the Yeovilian beyond the geographical limits of this paper, with the possible location of further deposits of low-grade ironstone, a little may be said here. Considering only the ironstones from north-west to south-east across nearly all the folds detected, the pre-Dogger structure is that of a small synclinorium, with a maximum downfolding in the region of the two worked ironstones, and with decreasing intensities to the north and south. It will, therefore, be unlikely that further Yeovilian ironstones will be found in these directions unless fold-complexes at present unknown be located.

A second factor must also be taken into consideration, that is the

original extent of the low-grade ironstone. It is clear that at the Nab (p. 206) the pebbly and argillaceous succession is only that of a depositional margin to the main mass of ironstone. To the north the micaceous chamosite-oolite of Stanch Bullen, in Great Fryup (Rastall and Hemingway, 1943, p. 222), is of entirely different facies from that of Rosedale East, the two being separated by a ridge which supplies the pebbles found in the ironstone of the Nab. Further, the interfingering clays in the ironstone in the High House section and the quartz silt in the matrix of the chamosite-oolite of the Hollins Basin again suggests a marginal facies of the original ironstone " lagoon ". It may therefore be concluded that the Yeovilian ironstone did not originally extend far beyond the present limits of Rosedale.

No Yeovilian has yet been seen to the west in Bilsdale or on the western Cleveland escarpment. To the east, Yeovilian beds have long been recorded on the downthrow side of the Peak Fault [1] (Fox-Strangways and Barrow, 1915, p. 116, etc.) where they are thickening southwards into a pre-Dogger basin when they dip below sea-level (Rastall and Hemingway, 1939, p. 365). The Peak Fault is probably torn sinistrally and certainly Yeovilian deposits do exist between its southern extent and Rosedale. Lamplugh's unpublished notes on the Crosscliff bore (inset in Text-fig. 1) about 12 miles E.S.E. of Rosedale Abbey (Lamplugh, 1920, p. 44) which have recently been discovered, specifically deny the presence of " Blea Wyke Sands and Shales " (i.e. Yeovilian) in the bore-hole. Yet he records the following below the Dogger and above the Alum Shales :—

	ft.
" Micaceous and rather sandy shale : no fossils seen in the top 6 feet, but a few belemnites below : not many fossils in first 15 feet	15
Shales with many belemnites and shells of *Lima* type	20 "

From their lithology, belemnite content and stratigraphical position these beds may only be correlated with the Blea Wyke Beds of Yeovilian age. The overlying " Dogger " core had been removed at the time of Lamplugh's examination and its thickness and lithology were not recorded. It is therefore not possible to determine if a new fold-complex with ironstone is located near here, though certainly a single pre-Dogger basin is present. It may be compared, in its apparent isolation, to the localized patch of Yeovilian, also preserved in a pre-Dogger syncline and exposed in Roxby Beck, near Loftus (Rastall and Hemingway, 1943, Text-fig. 1).

The Distribution of the Rosedale Magnetite-Oolite

The field relationships of the two elongate masses of magnetite-oolite in south-west Rosedale are discussed here without prejudice to

[1] The detailed structure of the Peak Fault is under investigation by the junior author.

their age. They are Kitching's deposit to the north and Garbutt's deposit to the south, and each was from 5 to 6 acres in extent, with a maximum width of 150 yards and a maximum depth of about 32 yards (Marley, 1879–80). The sides of the " shale cheeks " on which the deposits rest were " irregular and shelvy " and on them occasional waterworn pebbles were found. These shale cheeks are still in part exposed in the opencast part of the workings (p. 215), where they show evidence of slickensides. Serial sections across the deposits show how they decreased in size to the west, until they terminated at about 440 yards and 600 yards respectively from their original outcrops, after some minor faulting. They also show that the floors of these trough-shaped deposits were irregularly inclined and that Garbutt's deposit almost thinned out 200 yards from its outcrop before swelling out again for a further 200 yards. The two deposits are never in contact and though sometimes spoken of as nearly parallel, would undoubtedly have met had they extended a hundred yards further west.

In his descriptions, upon which the above paragraph is based, Marley emphasizes that " the top seam actually overlies the magnetic stone at the quarry, forming the roof of the magnetic stone in drifting " (Marley, 1879–80, p. 194, etc.). The Top Seam is the term by which the Dogger (*s.l.*) was usually known by the ironstone miners, irrespective of its iron content, and in this case is the Ajalon facies, which is exposed on the flanks of the old workings. Its basal pebble bed is the same as that between the magnetite deposit and the Top Seam (Marley, 1879–80, p. 198). From this it is clear that the magnetite-oolite deposits are pre-Blakey Series in age. Further than this cannot be argued with certainty, though it is tempting to assume that they also predate the youngest Dogger of the district, but since these die out before reaching the magnetite mines this is unproven.

There is no evidence that the magnetite-oolite deposits are preserved in pre-Dogger tectonic basins, as are the low-grade ironstones further north. Although the original outcrop of the magnetite-oolite does coincide with the middle of the Hollins Basin, this is purely fortuitous, since the basin is elongated approximately north-east–south-west, whilst the magnetite deposits run almost east–west. Although evidence of pre-Dogger folding is not lacking, it was of insufficient intensity to preserve these two adjacent deposits in relatively deep tectonic basins. Indeed, the truncation of the several beds of the Yeovilian by the magnetite deposits is directly opposed to it. All evidence tends therefore to confirm the early view that the magnetite-oolite deposits lie in deep and narrow channels (Marley, 1879–80 ; Lamplugh, 1920, p. 28), cut in beds of *dispansum* and *striatulum* age. From the presence of waterworn pebbles on their shelving flanks, the channels are presumably stream-cut. They have been compared with the channels

filled with Dogger limestone and low-grade ironstone in Bilsdale, 10 miles to the north-west (Lamplugh, 1920), since proved to be of *murchisonae* and probably *scissum* age (Black, 1934), but the two groups differ profoundly in form. Although of the same maximum depth, those of Bilsdale are about ten times wider than the Rosedale troughs, while the Bilsdale group indicate a normal series of incised meanders, which are apparently continuous within the limits of outcrop, very different from the low-angle Rosedale pair. The Rosedale magnetite was characterized by " the entire absence of shells " (Wood, 1859), nor have any macroscopic or microscopic fossils been found in the few fragments which may now be collected. This is in contrast with the shell-bands and lamellibranch and echinoderm debris which make up much of the Bilsdale Dogger.

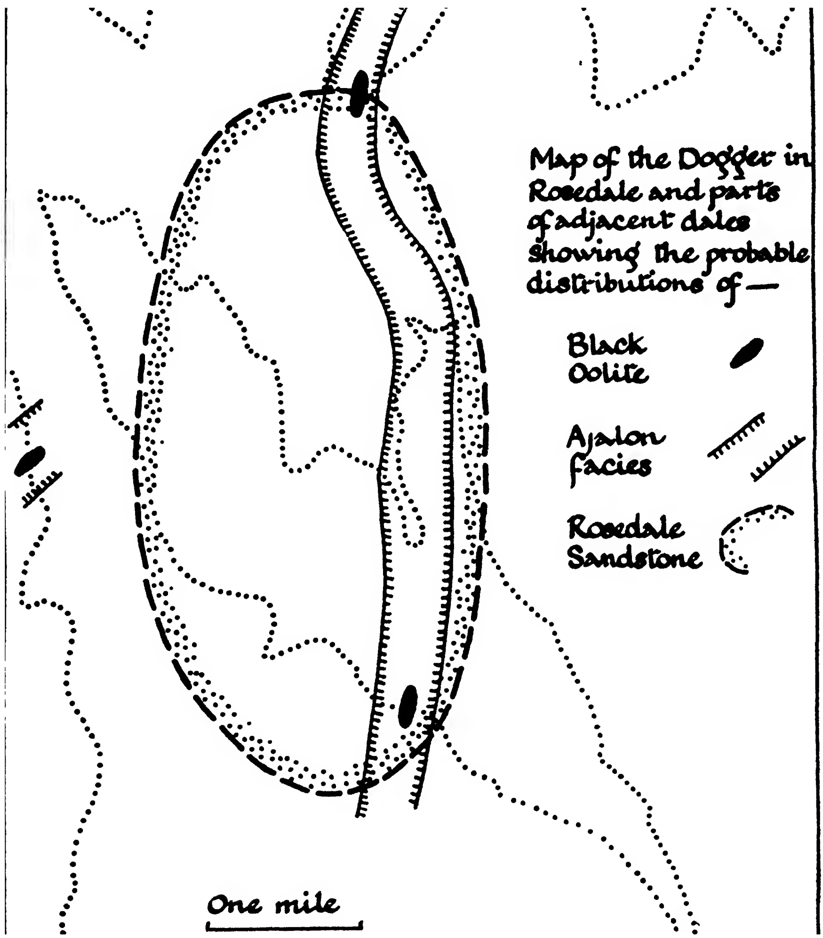
The Distribution of the Dogger

The distribution of the thin Rosedale Sandstone is shown in Text-fig. 6. Its relation to the main synclinorium is significant, in that it overlies the region of maximum pre-Dogger folding, near the old ironstone mines, and though its distribution was controlled by the down-warping which continued throughout Middle Jurassic times it was not influenced by Caledonoid folding.

The succeeding Black Shales and Green Flags facies are widespread and extend far to the west of Farndale. They, in turn, are followed by a platy green sandstone, which is succeeded by the Woodhead Scar sandstone, and finally by the various members of the Ajalon Series. In an earlier paper (Rastall and Hemingway, 1943, p. 213) we considered that these rocks were in chronological sequence, though each may have been partially or entirely removed by intra-formational erosion. However, the better exposed Rosedale sections and particularly those from Reeking Gill to Rosedale East Mines (pp. 204–10) admit the alternative interpretation of facies variation within this group of sandy rocks now referred to as the Blakey Series. This is supported by the absence of erosion surfaces between the several lithological types and by the gradual passage of one type to another in sections often continuous over many score of yards. Thus, from N.N.W. to S.S.E. the rocks above the Black Shales become progressively coarser in grain ; they pass from thin current-bedded flags to massive sandstones, etc. : and from non-oolitic to markedly oolitic and from chamositic to sideritic cements. Further, the thickness of these rocks is usually 10 feet to 12 feet ; in this they show a uniformity which would be unlikely if they had suffered successive episodes of erosion and deposition. Again, it would be most unlikely that intra-formational erosion would remove a sandstone, e.g. the Green Flags and fail to remove almost any part of the underlying Black Shales or leave evidence

of such erosion in the form of pebble beds. Gradual passage from the Black Shales to the overlying sandy beds is indeed common. The weight of evidence is therefore strongly in favour of facies variation.

It would appear reasonable to interpret this succession as indicating shallow inshore conditions in the Northdale region, where were laid



TEXT-FIG. 6.—Sketch map of Rosedale and parts of adjacent dales showing the probable original distribution of the Rosedale Sandstone, the Ajalon facies, and the Black Oolite.

down massive, ill-graded, and pebbly Dogger sediments, mixed with ooliths derived from contemporary deposits. These were subsequently cemented with siderite. To the west lay deeper water and a less disturbed environment, where by contrast cementing chamosite was deposited interstitially among the well-bedded and finer detrital

sediment. It is noteworthy that in the Reeking Gill–Rosedale East sections the coarser or more massive or more oolitic beds always overlie the finer or more flaggy or less oolitic beds. The several facies belts thus moved progressively westwards or north-westwards, presumably under gradual emergence of the regions to the east. The Black Oolite of Ewe Grain and Rosedale Bank is probably therefore an inshore sand which acted as a stratigraphic oil trap under an impervious cover of clays of the Lower Deltaic Series, the oil being subsequently absorbed into the weathered ooliths and now existing in only a carbonized form.

(To be continued.)

New Lower Ordovician Brachiopods from the Llandeilo-Llangadock District

PART II

By ALWYN WILLIAMS

(PLATE XI)

(*Continued from p. 174*)

Orthacea Walcott and Schuchert 1908

ORTHIDAE Woodward 1852 emend. Schuchert and Cooper 1932

Hesperorthinae Schuchert and Cooper 1931

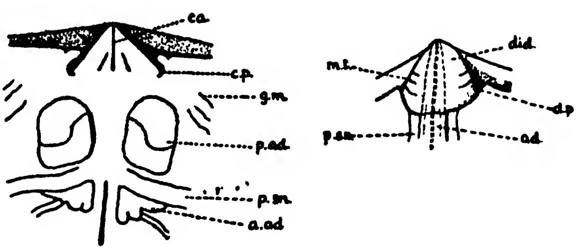
Hesperorthis Schuchert and Cooper 1931

Hesperorthis dynevorensis sp. nov.

Pl. XI, figs. 1 and 2, Text-fig. 1

Dimensions.—

			Length. cm.	Breadth. cm.
Syntypes.				
(1)	Internal mould of dorsal valve	G.S.M. 75,259	2·2	2·6
(2)	Internal mould of ventral valve	G.S.M. 75,260	2·3	2·5 (est.)
(3)	,, ,,	G.S.M. 75,261	—	—



TEXT-FIG. 1 (*a*).—Dorsal postero-lateral region of *Hesperorthis dynevorensis* sp. nov. (syntype 1). × 1½ approx. a.ad., anterior adductor; ca., cardinal process; c.p., crural process; g.m., genital markings; p.ad., posterior adductor; p.sn., pallial sinus.
(*b*).—Ventral umbonal region of *Hesperorthis dynevorensis* sp. nov. (syntype 2). × 1½ approx. ad., adductor scar; did. diductor scar; d.p., dental plate; m.t., muscle track; p.sn., pallial sinus.

External characters.—Plano-convex with a moderately deep ventral valve and a plane to slightly convex dorsal valve. Outline is semi-oval with the greatest width just anterior to the long straight hinge-line. Ventral interarea, wide, long, apsacline, dorsal interarea, anacline.

Ribbing.—Costate, 32 to 34 simple primary ribs, set rather apart, with the interspaces crenulated by lines of growth.

Internal characters.

Dorsal valve.—Hinge-line forming a thick " bar " supporting the notothyrial cavity, which extends postero-dorsally and is bounded laterally by two lamellar rudimentary crura projecting anteriorly.

The notothyrial cavity contains medianly a thin rod-like cardinal process which narrows to a point posteriorly. A pair of deep sockets lie lateral to the crura.

The " bar " effect of the hinge-line is such that the posterior adductors, an oval pair of scars notched on the inside, are indented somewhat into the " bar ". A median ridge extends anteriorly from the " bar " and bears on its surface a faint, thin, longitudinal impression. The posterior adductors are separated from the smaller anterior, somewhat flabellate, adductors by a pair of prominent vascular trunks which bifurcate laterally. A smaller pair of branches arise from the anterior adductor and divide into two peripherally. Genital markings are visible postero-laterally. Periphery bears impressions of costae split medianly.

Ventral interior.—Delthyrial cavity, deep, open. Crural fossettes small. Teeth small, supported by a pair of strong dental lamellae. A bounding ridge of adventitious matter encloses the muscular area almost completely, but medianly it is subordinate to the impression of the adductor scar. Two adductor scars, thin and long, separated by a fine ridge, project considerably beyond the diductors. Diductor scars, broad, triangular, contained within the delthyrium, and bearing oblique muscle tracks. Pallial markings obscure, a pair of primaries arising from the anterior limits of the diductors. Periphery ribbed, with split costae.

Type horizon.—Lower Pebble Bed of Upper Llanvirn.

Type locality.—Outcrop, 100 yards S. of the Old Castle, Dynevor, Llandeilo.

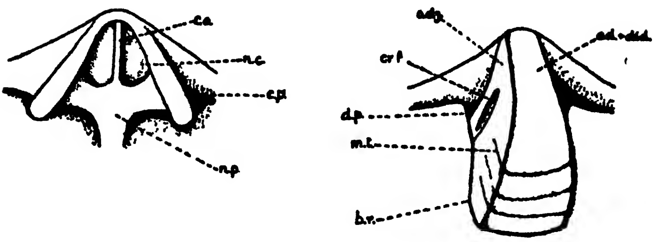
Discussion.—The new species may eventually prove to be quite distinct from *Hesperorthis*, for it is unique in the absence of ventral ovarian impressions, rudimentary deltidium and chilidium, and in having the anterior adductor smaller than the posterior in the dorsal valve. The former structures, however, seem to be somewhat variably developed and the dorsal valve of *Hesperorthis tricenaria* (Conrad) figured by Schuchert and Cooper (1932, pl. 4, fig. 21) also shows the anterior adductor scars smaller than the posterior ones.

It is interesting to note that *H. dynevorensis* bears a close internal resemblance to *Dolerorthis psygma* and *D. reedi* (Lamont and Gilbert 1945, pp. 645–651), and the dorsal valve is very much like that figured by them as the dorsal interior of *Dolerorthis rustica* (fig 2, p. 650). Indeed, the only fundamental diagnostic character which immediately distinguishes this new species from the Dolerorthids is the reversed convexity of the valves, and it is this characteristic that the author has used for the generic distinction between *Hesperorthis* and *Dolerorthis* (see Lamont and Gilbert, p. 649).

Paurorthis Schuchert and Cooper 1931

Paurorthis turgida (McCoy) emended

Pl. XI, figs. 9, 10, and 11, Text-fig. 2



a *b*

TEXT-FIG. 2 (*a*).—Cardinalia of *Paurorthis turgida* (McCoy) (new material 3). × 3. ca., cardinal process; c.p., crural process embedded in adventitious matter; n.c., notothyrial cavity; n.p., notothyrial platform.

(*b*).—Ventral umbonal region of *Paurorthis turgida* (McCoy) (new material 1). × 3. ad. & did., fused adductor and diductor scars; adj., ? adjustors, scar; b.r., bounding ridge to muscle scar; cr.f., crural fossette; d.p., dental plate; m.t., muscle track.

Orthis turgida McCoy 1851, 399–400 *pars.*

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, fig. 21, *non* figs. 20, 22, 23, 24.

Orthis turgida Davidson 1871, 258, pl. xxxii, fig. 13, *non* figs. 10–12, 14–20.

Orthis turgida Davidson 1883, 187, pl. xiv, fig. 20, *non* figs. 17–19.

Linoporella ? *turgida* Schuchert and Cooper 1932, 150–2.

Orthis turgida was first described by McCoy in 1851, and again in 1852, the later description being accompanied by illustrations of specimens which formed the basis of his diagnosis. The figured types were collected from a variety of places: pl. 1H, figs. 20 and 20*a*, represents an external cast of a dorsal valve from the Llandeilo Limestone (A16,679); fig. 21 an internal mould of a ventral valve from Golden Grove, Llandeilo (A11,100); figs. 22 (A16,680) and 23 (A11,101), internal moulds of dorsal valves from Craig-y-beri, and the Hills north of Conway respectively; fig. 24 represents a reconstructed anterior view of conjoined valves, but is a composite representation and need not be considered further. It now appears that all the figured dorsal valves are generically distinct from the figured ventral valve. The former are described below as Corineorthis spp. and the latter is here chosen as the lectotype for *P. turgida* emended.

This ventral valve is preserved in a rather coarse ashy sandstone, which could only have come from the quarry of Ffairfach Grit, .at Golden Grove. No specimens comparable with it have been collected

from this locality, but at Ffairfach numerous ventral valves conspecific with that from Golden Grove and associated with dorsal valves described below have been obtained from strata some 50 feet above the horizon of the Golden Grove locality.[1] Accordingly new material has been chosen from among the Ffairfach specimens to provide a complete description of *P. turgida* emended.

Dimensions.—		*Length.* cm.	*Breadth.* cm.
Lectotype.			
Internal mould of ventral valve	S.M.A. 11,100	1·0	—
New material.			
1. Internal mould of ventral valve	G.S.M. 75,255	1·8	1·7
2. ,, ,,	G.S.M. 75,256	1·3	1·1
3. Internal mould of dorsal valve	G.S.M. 75,257a	1·5	1·6
4. ,, ,,	G.S.M. 75,257b	1·2	1·3
5. External impression of interareas and portions of both valves	G.S.M. 75,258	—	—

External characters.—Sub-circular in outline with a wide hinge-line (not the greatest width of the shell, which is anterior to the hinge-line). Strongly bi-convex, the ventral valve sometimes slightly more so than the dorsal. Ventral interarea curved, apsacline; dorsal interarea anacline, notothyrium, and delthyrium open. Ornamentation poorly preserved, multicostellate, with strong concentric lines of growth.

Internal characters.

Ventral valve.—Delthyrial cavity moderately deep, teeth conspicuous, with accessory sockets. Crural fossettes distinctive, oblique, and substantiated by a thick fossette ridge. Dental plates short, continued anteriorly by ridges of adventitious matter to form a lateral boundary to the musculature. Muscle scar sub-rectangular; in mature shells up to half the length of the shell and almost three times as long as wide. In young and mature shells the adductor and diductor scars occupying two slight, parallel tumescences are seen to extend anteriorly beyond the adjustors (?) which occupied the dental plates and part of the delthyrial cavity. In gerontic individuals the muscle scar is rather obscured by the presence of muscle tracks and the thickened boundary only breaks down anteriorly.

Dorsal valve.—Notothyrial cavity shallow, bounded by two divergent blunt brachiophores supported by adventitious material which also builds up a bulbous notothyrial platform. Sockets lateral to the brachiophores are not deeply impressed. Cardinal process forms à simple rod. The notothyrial platform is continued anteriorly as a

[1] The matrices for the lectotype and the new material seem to be identical and the fact that *P. turgida* has only been collected from this one locality in the Llandeilo area where, however, numerous casts can be obtained, suggests that the Ffairfach cutting was the actual locality for the lectotype as well.

broad high septum which divides the brachial valve into two and tends to splay out at the anterior margin. Muscle scars are not distinguishable.

Type horizon.—Upper Llanvirn.

Lectotype locality.—Quarry, 1 mile W. of Golden Grove mansion, Llandeilo.

New material.—Ffairfach railway cutting, 60 yards S. of the level-crossing.

Discussion.—Schuchert and Cooper (1932, p. 151) provisionally placed *P. turgida* in the Dalmanellid genus *Linoporella* on the characters exhibited by the dorsal valve, which, as seen above, does not belong to *P. turgida* emended. *P. turgida* can be relegated to the genus *Paurorthis* Schuchert and Cooper on its external and internal characters, but differs from typical species in its much larger size, in the absence of the median septum of the ventral valve, and the absence of ovarian impressions. None of these, however, would seem to warrant generic recognition. The ventral septum is "not constant in all specimens [of *Paurorthis*], some having a rather wide median undulation" (Schuchert and Cooper, 1932, p. 80), and the absence of ovarian markings may even be due to the coarseness of the matrix in which the specimens are preserved.

PLECTORTHIDAE Schuchert and Cooper 1930

Corineorthis Stubblefield 1939

Corineorthis pustula sp. nov.

Pl. XI, figs. 3–6, Text-fig. 3

Orthis turgida McCoy 1851, 399–400 *pars.*

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, figs. 20, 22, 24, *non* figs. 21, 23.

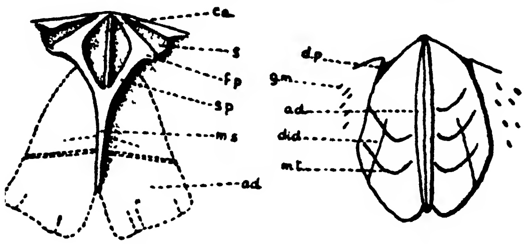
Orthis turgida Davidson 1871, 258 *pars*, pl. xxxii, figs. 12, 14, 16; ? figs. 17, 18, 19, 20; *non* figs. 13, 15.

Orthis turgida Davidson 1883, 187 *pars*, pl. xiv, fig. 17, ? fig. 18, *non* figs. 19, 20.

Linoporella ? *turgida* Schuchert and Cooper 1932, 150–152

Dimensions.—		*Length.* cm.	*Breadth.* cm.
Syntype 1.			
External cast of dorsal valve A16,679		—	—
New material.			
1*a*. Internal mould of dorsal valve	G.S.M. 75,262	1·8	2·2
1*b*. External cast of dorsal valve	G.S.M. 75,263a	1·7	1·9
1*c*. Internal mould of ventral valve	G.S.M. 75,264	1·7	2·2
1*d*. External cast of ventral valve	G.S.M. 75,265	1·5	—

Dimensions.—		*Length.* *cm.*	*Breadth.* *cm.*
1*e*. Cardinalia of dorsal valve	G.S.M. 75,263b	—	—
1*f*. Internal mould of dorsal valve showing muscle scars	G.S.M. 75,266	—	—
Syntype 2.			
Internal mould of dorsal valve	A16,680	—	—
New material.			
2*a*. External casts of dorsal valve	A25,313, A25,315	1·6	1·7 (others fragmentary)
2*b*. Internal mould of ventral valve	A25,323	fragmentary	
2*c*. Internal mould of dorsal valve (young)	A25,321	1·0	1·1
2*d*. Internal mould of dorsal valve	A25,322	fragmentary	



a *b*

TEXT-FIG. 3 (*a*).—Cardinalia of *Corineorthis pustula* sp. nov. (new material 1*a*). × 3. ad., adductor scar ; ca., cardinal process ; f.p., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Corineorthis pustula* sp. nov. (new material, 1*c*). × 3. ad., adductor scar; did., diductor scar; d.p., mould of dental plate ; g.m., genital markings ; m.t., muscle tracks.

External characters.—Typical Orthoid outline to dorsal and ventral valves with the greatest width anterior to the hinge-line. Dorsal valve strongly convex, with a well-marked median sinus, widening very gradually anteriorly, umbo incurved. Ventral valve convex posteriorly, with a small umbo, but peripherally flat to concave.

Ribbing system.—Multicostellate on the primitive plan (with up to 12 primaries), viz. 1 primary, secondary (*a*), secondary (*b*), tertiary, but with a marked change from external to internal development (and vice versa) with the changing shape of the shell. Finely developed concentric ridges between ribs, coarsely exopunctate.

Dorsal valve.—

$1\bar{a}$, $1\bar{b}$, 1.
$2\overline{a1}$, $2\bar{a}$, $2\overline{a1}$, $2\bar{b}$, 2.
$3\overline{a1}$, $3\bar{a}$, 3, $3a^{\circ}$ (strong).
$4\bar{a}$, $4\overline{a1}^{\circ}$, 4b, 4, $4b^{\circ}$, $4a^{\circ}$, $4a1^{\circ}$.
$5\bar{a}$, $5\overline{a1}^{\circ}$, 5, $5b^{\circ}$, $5a^{\circ}$, $5a1^{\circ}$.
6, $6b^{\circ}$, $6a^{\circ}$, $6a1^{\circ}$.
7, $7b^{\circ}$, $7a^{\circ}$, $7a1^{\circ}$.
etc.

Ventral valve.—

$1a^{\circ}, 1b^{\circ}, 1, 1b^{\circ}, 1a^{\circ}, 1a1^{\circ}.$

Right.	*Left.*
$2\bar{a}, 2, 2b^{\circ}, 2a^{\circ}, 2a1^{\circ}.$	$2\bar{a}, 2, 2b^{\circ}, 2a^{\circ}, 2a1^{\circ}.$
$3, 3c^{\circ}, 3b^{\circ}, 3a^{\circ}, 3a1^{\circ}.$	$3\bar{a}, 3, 3c^{\circ}, 3b^{\circ}, 3a^{\circ}, 3a1^{\circ}.$
$4\bar{a}, 4, 4a^{\circ}\bar{1}, 4a^{\circ}, 4a1^{\circ}.$	$4\overline{a1}, 4\bar{a}, 4\bar{b}, 4, 4a^{\circ}\bar{1}a^{\circ}, 4a^{\circ}\bar{1}, 4a^{\circ}.$
$5\bar{a}, 5, 5a^{\circ}\bar{1}, 5a^{\circ}, 5a1^{\circ}.$	$5\overline{a1}, 5\bar{a}, 5\bar{b}, 5, 5a^{\circ}\bar{1}, 5a^{\circ}.$
$6\overline{a1}, 6\bar{a}, 6\bar{b}, 6, 6a^{\circ}\bar{1}, 6a^{\circ}.$	$6\overline{a1}, 6\bar{a}, 6\bar{b}, 6, 6a^{\circ}\bar{1}, 6a^{\circ}, 6a1^{\circ}.$
etc.	etc.

Internal characters.

Dorsal valve.—Cardinalia delicate, consisting of a pair of divergent crural processes and a slender, simple cardinal process contained within the notothyrial cavity. The crural processes are made up of a pair of supporting plates bounding the notothyrial cavity, and converging anteriorly to unite with the median septa, and a pair of fulcral plates which lie anterior to the deeply impressed dental sockets. Muscle scars faint, sub-triangular in outline, with the larger posterior adductors separated from the quadrangular anterior adductors by a ridge. Ribbing is impressed on the internal moulds of both valves.

Ventral valve.—Umbonal region rather deep with a pair of sub-parallel dental lamellae running anteriorly, and bounding laterally the pronounced muscular impression. The latter consists of a pair of diductor impressions, rounded anteriorly, separated by an elongated pair of adductors. Occasionally a pair of short divergent pallial sinuses are preserved, lying immediately anterior to the muscle scar. The areas lateral to the muscle scars are coaısely pustuled, with genital markings.

Type horizon.—Lower Llandeilo.

Type localities.—Syntype 1, Llandeilo, exact locality unknown. New material (*1a–1f*), outcrop 75 yards S.W. of St. Tyfei's Church, Llandeilo. Syntype 2 and new material (*2a–2d*), Craig-y-beri, Llanarmon.

Discussion.—The new species is a Corineorthid, but differs from the type species *Corineorthis decipiens* Stubblefield in the following characters.

(1) The greater convexity of the dorsal valve, with corresponding emphasis of the sinus.

(2) The greater emphasis of the muscle scars.

(3) The ventral valve of *Corineorthis pustula* is always coarsely pustulated postero-laterally.

Corineorthis globosa sp. nov.

Pl. XI, figs. 7 and 8, Text-fig. 4

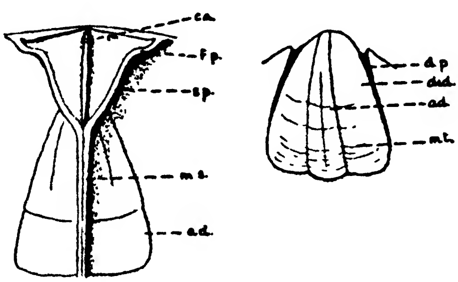
Orthis turgida McCoy 1851, 399–400 *pars.*

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, fig. 23, *non* figs. 20–22, 24.

Orthis turgida Davidson 1871, 258 *pars*, fig. 15, ? figs. 17, 18, 19, 20, *non* figs. 12, 13, 14, 16.
Orthis turgida Davidson 1883, 187 *pars*, fig. 19, *non* figs. 17, 18, 20.
Linoporella ? *turgida* Schuchert and Cooper 1932, 150–152.

Dimensions.—

		Length. *cm.*	*Breadth.* *cm.*
Holotype.			
Internal mould of dorsal valve	A11,101	1·3	1·3
New material.			
Internal mould of dorsal valve	A25,304	1·3 (est.)	1·5
Internal mould of ventral valve	A25,305	Posterior portion	
Fragment of external cast of ? dorsal valve	A25,306		



a *b*

TEXT-FIG. 4 (*a*).—Cardinalia of *Corineorthis globosa* sp. nov. (A11,101). × 3, ad., adductor scar ; ca. cardinal process ; f.p., fulcral plate ; m.s., median septum ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Corineorthis globosa* sp. nov. (A25,305). × 3. ad., adductor scar ; did., diductor scar ; d.p., mould of dental plate ; m.t., muscle tracks.

External characters.—Subcircular in outline, with the greatest width anterior to the hinge-line. Subequally bi-convex, the dorsal valve globose, the ventral valve gently convex posteriorly. Valves ornamented by multicostellate ribbing and by occasional coarse, concentric lines of growth. Ventral interarea apsacline, dorsal interarea anacline-hypercline.

Internal characters.

Dorsal valve.—Cardinalia rather delicate, with a pair of widely divergent crural processes on either side of the notothyrial cavity, which contains a simple linear cardinal process. The crural processes consist of a pair of supporting plates, which converge with the median septum anteriorly, and a pair of splayed fulcral plates, forming anterior boundaries to the dental sockets. Median septum narrow, high, extending to half the length of the valve. Adductor scars deeply impressed, lateral boundaries well defined. Postero-lateral areas striated by genital markings. Ribbing very faintly impressed.

Ventral valve.—Delthyrium triangular, open; teeth supported by a pair of strong dental plates which extend anteriorly to form lateral boundaries to the strongly impressed muscle scar. Adductor scar moderately wide, median, and bounded by a pair of diductors traversed by muscle track impressions.

Type horizon.—Lower Bala.

Type locality.—" Hills N. of Conway Falls."

Discussion.—The new species is distinct from *Corineorthis decipiens* Stubblefield and *C. pustula* sp. nov. in its extremely globose dorsal value, the widely splayed fulcral plates, the strong muscle dorsal impressions, the presence of genital striae postero-laterally in dorsal moulds, and the wider adductor scar in the ventral valve. Except for the marked convexity of the dorsal valve, *Corineorthis globosa* is very like *C. salteri* (Davidson), and this group of shells may eventually prove distinct from *Corineorthis* (s.s.).

Strophomenacea Schuchert 1896

PLECTAMBONITIDAE Kozlowski 1929

Sowerbyella Jones 1928

Sowerbyella antiqua Jones var. *llandeiloensis* var. nov.

Pl. XI, fig. 12–14

Dimensions.—

		Length. *cm.*	*Breadth.* *cm.*
Syntypes.			
(1) External cast of ventral valve	G.S.M. 75,267	0·8	1·55
(2) Internal mould of ventral valve	G.S.M. 75,268	0·8	1·7 (est.)
(3) Internal mould of dorsal valve	G.S.M. 75,269	0·7	1·4
(4) External cast of dorsal valve	G.S.M. 75,270	0·7 (est.)	1·4 (est.)

External characters.—Semi-oval in outline, widest at the hinge-line, which is mucronate. Ventral valve is strongly convex, carinate, dorsal valve concave. Ornamentation fine, radial, consisting of a series of thread-like ribs averaging 7 to 8 per mm., with every fourth or fifth strongly accentuated and extending to the umbo.

Internal characters.

Ventral valve.—Comparable with *S. antiqua*, except that the umbonal region is deeper, and the septal groove dividing the adductors impressions more definite. In gerontic individuals a pair of vascular trunks are seen to arise from the muscular impressions, and reach almost to the anterior border, where they bifurcate. The muscle scars are bounded by a pair of thin, slightly divergent dental lamellae.

Dorsal valve.—Like *S. antiqua*, but the muscle scar is very markedly raised anteriorly and is distinctly divided by a median septum, and by four lateral septa, and the periphery is coarsely pustuled.

Type horizon.—Upper Llanvirn and Lower Llandeilo.

Type localities.—Syntypes (1) and (3) from outcrops 5 yards N. of Old Dynevor Castle, Llandeilo. Syntypes (2) and (4) from Quarry, 75 yards W. of Boathouse, Dynevor, Llandeilo.

Discussion.—The new variety is comparable with and pene-contemporary to *S. antiqua*, but externally it differs in the finer ribbing, the differentiation into primaries, the semi-oval outline, with the "winged" hinge-line and the larger size. Internally, all characters, when compared with *S. antiqua*, are emphasized: e.g. the deeper umbonal region of the ventral valve; the elevation of the muscular area, and the pustules of the dorsal valve.

Rhynchonellacea Schuchert 1896

CAMAROTOECHIIDAE Schuchert and Le Vene 1929

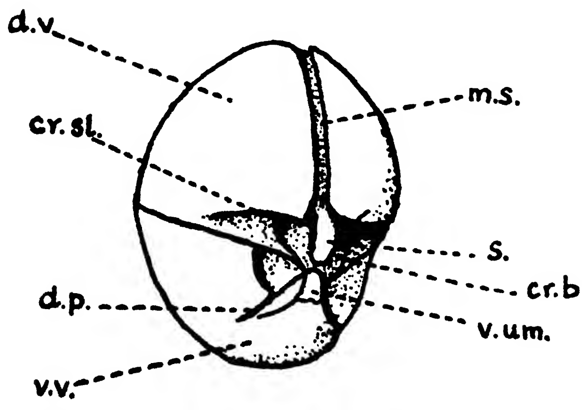
Rostricellula Ulrich and Cooper 1942

Rostricellula triangularis sp. nov.

Pl. XI, figs. 15–18, Text-fig. 5

Dimensions.—

Syntypes.		*Length. cm.*	*Breadth. cm.*
(1) Internal mould of dorsal and ventral valves interlocked	G.S.M. 75,229	—	—
(2) Internal mould of ventral valve	G.S.M. 75,230	0·85	1·0
(3) External cast of Syntype (2)	G.S.M. 75,232a	0·85	1·0
(4) Internal mould of dorsal valve	G.S.M. 75,231	0·85	1·0
(5) External cast of Syntype (4)	G.S.M. 75,232b	0·85	1·0



TEXT-FIG. 5.—Posterior view of *Rostricellula triangularis* sp. nov. (syntype 1). × 10 approx. d.v., dorsal valve; v.v., ventral valve; cr.b., crural base; cr.s., crural slot; d.p., dental plate; m.s., median septum; s., mould of septalium; v.um., ventral umbo (broken).

External characters.—Both valves about as wide as long, triangular in outline, with the greatest width at two-thirds the length. Moderately and subequally bi-convex, the dorsal valve having a broad, well defined fold, the ventral valve a complementary sulcus. The surface is ornamented with large radiating primary plications, three in the sulcus of the ventral valve, five on the fold of the dorsal valve, with five to six on either side.

Internal characters.—Best studied in the interlocked internal moulds of the dorsal and ventral valves of the holotype.

In the dorsal valve the hinge-line is short and somewhat curved, the median septum is well defined, reaching half the length of the valve, and posteriorly bifurcating to form a minute spindle-shaped septalium which does not contain a cardinal process. The sides of the septalium are fused to the hinge-line by a pair of acutely triangular, slightly concave plates (termed the "crural bases" by St. Joseph, 1937). It is undecided whether these are discrete or whether they are an extension of the hinge-line, but together with the split septum they simulate the socket and supporting plates of the Dalmanellids, and indeed have the same function, for the bases of the triangular plates support a pair of short simple crura diverging slightly anteriorly.

In the ventral valve the umbo is moderately high and bent over. From the disposition of the component parts it is deduced that the foramen is sub-apical (nothing is known of the deltidium). The teeth are strong, closely set, triangular in shape, resting upon the concave areas of the crural bases, and are supported by a pair of dental lamellae, bent sharply anteriorly, which appear as slots in moulds. No muscle scars have been observed. Ribbing is impressed in internal moulds of both valves.

Type horizons.—Upper Llanvirn and Lower Llandeilo.

Type localities.—Syntype (1) : Upper Llanvirn outcrops in stream 200 yards N.W. of Bryntowy Farm, 1¾ miles S.S.W. of Llangadock. Other Syntypes : old quarry of Lower Llandeilo flags, 300 yards W. of Ysgubor-wen Farm, 1¼ miles E. of Llandeilo.

The new species is rather like *Rostricellula rostrata* Ulrich and Cooper, genotype of the genus, but differs in having a more triangular outline and a less globose contour than the latter.

The genus is interesting in that it probably includes species which were ancestral to the Silurian Rhynchonellids, viz. *Rhynchotreta* and *Camarotoechia*. Hall (1894) in his revision of the Rhynchonellids gave, as the prime distinction between *Rhynchotreta* and *Camaroteochia*, the presence of a cardinal process in the former and its absence in the latter. In 1937 St. Joseph, in two illuminating papers respectively dealing with the genoholotypes of *Rhynchotreta* and *Camarotoechia*,

pointed out that in fact a cardinal process was absent in *Rhynchotreta* as well as *Camarotoechia*, and presented a valid case for using such characters as dentition, and the presence of a septalium as the chief diagnostic characters of the respective genera. Following upon this, the specimens described above bear a strong resemblance to *Camarotoechia* in the possession of a true medium septum and a septalium. The crura, however, with their narrow crural bases, the strong triangular teeth of the ventral valve, together with the distinct dental lamellae supporting them are all characteristic of *Rhynchotreta.*

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PLATE

All figures 1½ times natural size except where indicated.

Hesperorthis dynevorensis sp. nov.

FIG. 1.—Internal mould of dorsal valve (G.S.M. 75,259).
FIG. 2.—Internal mould of ventral valve (G.S.M. 75,260).

Corineorthis pustula sp. nov.

FIG. 3.—Internal mould of dorsal valve (G.S.M. 75,262).
FIG. 4.—Internal mould of ventral valve (G.S.M. 75,264).
FIG. 5.—External cast of dorsal valve (A16,679).
FIG. 6.—Internal mould of dorsal valve (A16,680).

Corineorthis globosa sp. nov.

FIG. 7.—Internal mould of ventral valve, posterior aspect (A25,305).
FIG. 8.—Internal mould of dorsal valve (A11,101).

Paurorthis turgida (McCoy) emended.

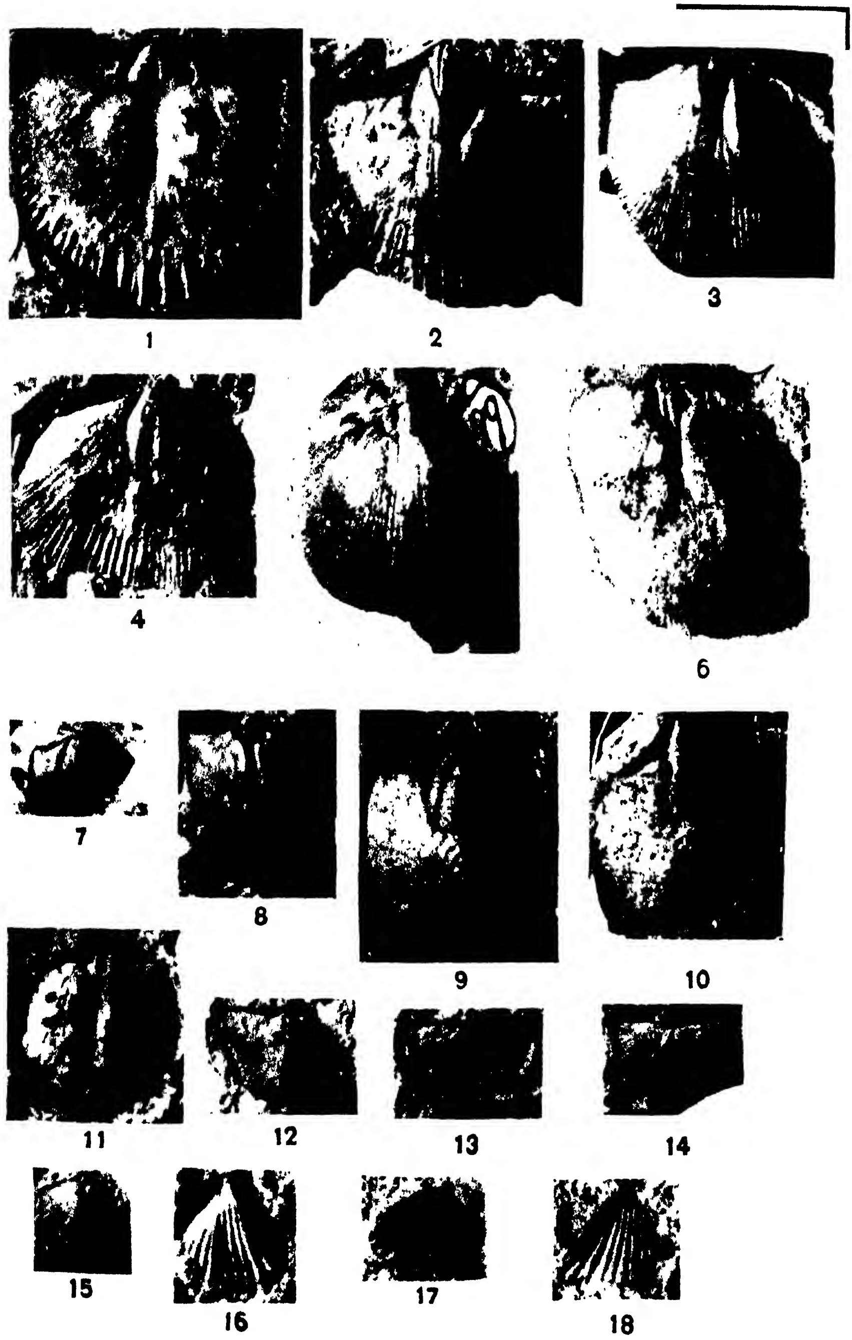
FIG. 9.—Internal mould of ventral valve (A11,100).
FIG. 10.—Internal mould of ventral valve (G.S.M. 75,255).
FIG. 11.—Internal mould of dorsal valve (G.S.M. 75,257a).

Sowerbyella antiqua var. *llandeiloensis* var. nov.

FIG. 12.—Internal mould of ventral valve (G.S.M. 75,268).
FIG. 13.—Internal mould of dorsal valve (G.S.M. 75,269).
FIG. 14.—External cast of dorsal valve (G.S.M. 75,270).

Rostricellula triangularis sp. nov.

FIG. 15.—Internal mould of dorsal valve (G.S.M. 75,231).
FIG. 16.—Internal mould of ventral valve (G.S.M. 75,230).
FIG. 17.—External cast of dorsal valve (G.S.M. 75,232b).
FIG. 18.—External cast of ventral valve (G.S.M. 75,232a).



NEW LOWER ORDOVICIAN BRACHIOPODS.

The Gare Loch Re-advance Moraine[1]

By J. G. C. ANDERSON

ABSTRACT

Detailed drift mapping near the Gare Loch, Dumbartonshire, has confirmed that the loch was formerly occupied by a late valley glacier marking a re-advance contemporaneous with re-advances in the Loch Lomond and Upper Forth Valleys. The moraine of the Gare Loch glacier, which has been traced for some miles on both sides of the loch, locally rests on clays of the "100-ft." sea and is overlain by "25-ft." beach gravels.

INTRODUCTION

THE Gare Loch is one of the best known of the numerous arms of the sea which extend from the north side of the Firth of Clyde into the South-West Highlands. It branches from the Firth just west of Helensburgh, Dumbartonshire, and runs in a north-westerly direction for six miles. For the most part the Gare Loch penetrates Dalradian schistose grits and slates. Near its mouth, however, sandstones and conglomerates of Upper Old Red Sandstone age are present, brought against the Dalradian rocks by a north-easterly fault.

One of the most conspicuous features of the Gare Loch is Row Point, a narrow gravel headland projecting for half a mile from the eastern shore near the village of Row (Rhu). Row Point lies opposite another headland of similar type extending outwards from Rosneath on the western side of the Gare Loch. Between the two points the width of the loch is reduced at low tide to 200 yards, and the depth of the channel is about 30 feet compared with depths of nearly 100 feet not far to the north and south.

The earliest reference in geological literature to the headlands at Row and Rosneath appears to have been made by J. Anderson (1896, p. 198), who provides a map showing a glacier occupying the Gare Loch as far south as Rosneath. The author puts forward the view that the terminal moraine of this glacier is represented both by the gravel banks forming the points at Row and Rosneath and by raised beach deposits along the shores of the loch. In the case of the raised beaches he suggests that the action of the sea has destroyed the original morainic form.

Anderson's paper does not seem to have been given the attention it deserved, and until fairly recently it appears probable that most observers regarded the headlands in question as ordinary gravel spits formed solely by marine agencies. In 1936, however, McCallien (1936, p. 386) again suggested that Row Point marked the site of a moraine and gave a description of the section exposed on its north face.

[1] Published by permission of the Director, H.M. Geological Survey.

During 1946 and 1947 the present author re-mapped the district on the 6 in. scale in the course of a revision of Sheet 30 of the Geological Map. He not only found himself in full agreement with the previous workers already mentioned regarding the significance of Row Point, but was also able to trace the moraine on the hillside on both sides of the loch (Text-fig. 1).

Description

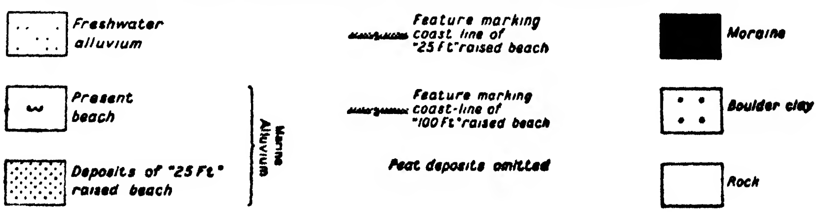
Row Point.—On the north-west side of Row Point wave action has exposed a section about 250 yards long and from 15 to 20 feet high, a description and sketch of which have already been given by McCallien (1936, Fig. 2). As the face is subject to minor landslips, the debris from which is periodically removed by storms, it shows changes from time to time in clarity and continuity. The thickness of the different beds also varies from point to point. A generalized section recorded by the writer in September, 1946, follows :—

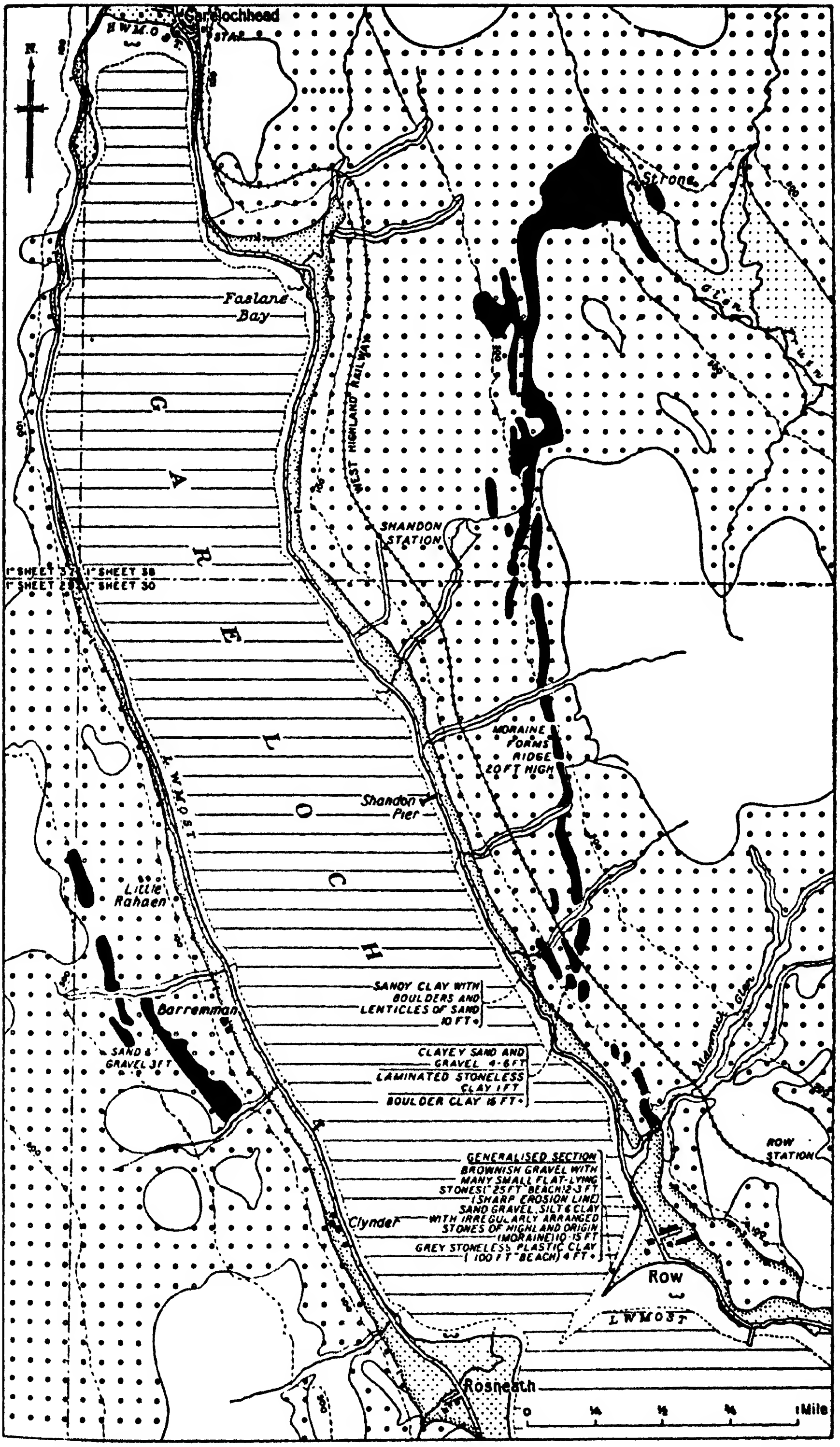
Brownish, well-bedded gravel with many small flat-lying stones.	2–3 ft.	" 25 ft." Raised Beach Deposit.
Sharp erosion line.		
Sand, gravel, silt, and clay, with irregularly arranged stones of Highland origin. (Base ill-defined owing to slipping.)	10–15 ft.	Moraine.
Grey, stoneless, plastic clay, with distorted bedding.	4 ft. +	" 100 ft." Raised Beach Deposit.

The morainic deposits are characterized by rapid lateral variation. In some places they appear unstratified ; in others they are well stratified and sometimes show current-bedding. The basal clay, which is finely laminated, is identical with that common in the " 100 ft. " beach deposits throughout much of the Clyde estuary. A small indeterminable shell-fragment was found by the author, and from a sample of the clay Mr. F. W. Anderson obtained ostracods (*Cytheropteron latissimum*), foraminifera, plant seeds, and beetle fragments.

East Side of Gare Loch.—Between Row Point and Aldownick Glen the moraine is hidden under " 25 ft. " raised beach deposits. A low feature, brought out by a slight but sharp rise on the main road near where it leaves the coast on the north side of the point, may mark

Text-fig. 1.—Map of Gare Loch Re-advance Moraine. (Opp.)




Garelochhead
N.
H.W.M.O.S.T.
Faslane Bay
G A R E L O C H
WEST HIGHLAND RAILWAY
SHANDON STATION
1" SHEET 37 1" SHEET 38
1" SHEET 29 1" SHEET 30
Strone
Glen Fruin
MORAINE FORMS RIDGE 20 FT HIGH
Shandon Pier
L.W.M.O.S.T.
Little Rahaen
Barremman
SAND & GRAVEL 3 FT
SANDY CLAY WITH BOULDERS AND LENTICLES OF SAND 10 FT +
CLAYEY SAND AND GRAVEL 4-6 FT
LAMINATED STONELESS CLAY 1 FT
BOULDER CLAY 16 FT +
GENERALISED SECTION
BROWNISH GRAVEL WITH MANY SMALL FLAT-LYING STONES ("25 FT" BEACH) 2-3 FT
(SHARP EROSION LINE)
SAND GRAVEL, SILT & CLAY WITH IRREGULARLY ARRANGED STONES OF HIGHLAND ORIGIN (MORAINE) 10-15 FT
GREY STONELESS PLASTIC CLAY ("100 FT" BEACH) 4 FT +
Aldernock Glen
ROW STATION
Clynder
Row
LWMOST
Rosneath
0 ¼ ½ ¾ 1 Mile

the face of the moraine. On the south side of the stream in Aldownick Glen, 320 yards upstream from the main road, morainic deposits, consisting of 5 feet of clayey sand with numerous irregularly arranged boulders, rest on 15 feet of stiff light-grey boulder clay with many small stones.

Between Aldownick Glen and Croy (five-eighths of a mile S.S.E. of Shandon Pier, Text-fig. 1) the moraine is represented by a line of low discontinuous mounds on the slope between the main road and the West Highland railway. A section in a stream 225 yards from Croy shows :—

Clayey sand and gravel with irregularly arranged boulders.	4–6 ft.
Laminated stoneless clay	1 ft.
Yellowish-grey boulder clay . . .	15 ft. +

The topmost beds are definitely morainic in character, and the laminated clay, which lies about the 100 ft. level is probably part of the " 100 ft. " beach deposits.

In half a mile northwards from Croy the moraine, marked by low mounds and shelves in the hillside, rises from the 100 ft. to the 400 ft. level, on the hillside above Shandon Pier. For half a mile north of this point the moraine is particularly striking, as it forms a ridge about 50 feet across and from 10 feet to 20 feet high, broken only where breached by small streams. One of these streams, flowing into the Gare Loch south of Shandon Pier, is diverted along the outside of the moraine for some 300 yards.

East of Shandon station the moraine lies about 500 feet above sea-level and is marked by two distinct lines of low mounds. The more easterly and higher line tails out against a steep slope, but the more westerly continues northwards as a comparatively broad zone of highly irregular mounds and ridges situated between the 500 and 600 ft. contours.

The moraine, marked by mounds 10 feet to 15 feet high, which small excavations show to consist of clayey sand with abundant stones, reaches its highest point, about 650 feet, a mile east of Faslane Bay. It then turns eastwards into Upper Glen Fruin where it is represented by low mounds, overlying boulder clay, between the 450 and 500 ft. contours in the vicinity of Strone. It is not possible to trace the moraine beyond this point as there is no sign of its presence on smooth boulder clay slopes to the north of Strone.

Between the moraine and the Gare Loch the solid rocks are mostly mantled in boulder clay, forming comparatively smooth slopes, which contrast strongly with the moundy morainic zone. West of Faslane Bay, however, the hillside is slightly hummocky and the surface appears

in places sandy or loamy. A thin spread of morainic drift may therefore overlie the boulder clay in this area but it is not sufficiently well defined to be mapped. Thin morainic drift may also be present about half a mile S.S.E. of Shandon Station where the surface is slightly hummocky, and cuttings along a railway siding show sandy deposits overlying the boulder clay. It is difficult to be certain whether these sandy deposits are truly morainic or are simply hill-wash. In the same cutting fine-grained schistose grits and slates which normally dip S.E. at about 45 degrees are bent over near the surface into the vertical or even slightly overturned towards the S.E. This is almost certainly due to the drag of ice moving down the Gare Loch.

Along the shore of the loch the " 25 ft. " beach is marked by a continuous shelf sloping gently upwards to a well-marked feature, the base of which lies about 35 feet above O.D. It is of significance that the " 100 ft. " beach, well developed between Helensburgh and Row, comes to an end in line with Row Point and has not been detected further up the Gare Loch.

West Side of Gare Loch.—There can be little doubt that the point at Rosneath is of the same character as Row Point, although there are no sections which reveal its internal structure. For 1¼ miles to the north no trace of the moraine could be detected. The hillside immediately above this part of the loch is steep, and rock is either at the surface or is covered by only a few feet of boulder clay.

A wood, half a mile long, at about the 300 ft. level west of Barremman appears to have been planted on the moraine, as the surface is frequently loamy or sandy and shows many small stones ; sand and gravel up to 3 feet thick are exposed in drains. It is possible that morainic deposits have here been spread out on the slope by solifluxion. West of the northern end of the wood poorly developed mounds are seen at about the 400 ft. level. These are continued north of the Meikle Burn (flowing into the Gare Loch north of Barremman) by an interrupted line of low, but clearly defined, mounds, which finally come to an end west of Little Rahaen, at about 400 and 500 feet above O.D., a height roughly corresponding with that of the moraine on the opposite side of the loch.

Conclusions and Correlations

The writer is in full agreement with previous workers that Row Point is of morainic origin. From the Point the moraine has been traced by the author more or less continuously for a distance of 4 miles on the east side of the loch. On the west side it is not so strongly developed, nor so continuous, but it has nevertheless been followed for a distance of 2½ miles. There can, moreover, be little doubt that the

moraine marks the limit of advance of a late valley glacier post-dating the " 100 ft. " beach deposits and pre-dating those of the " 25 ft. " beach. The Gare Loch re-advance must therefore have been contemporaneous with the Loch Lomond and Upper Forth readvances described by Simpson (1933, p. 633).

As the field work carried out by the author was confined to Sheet 30 and a small part of Sheet 38 it was not found possible to examine lochs and valleys farther to the west and north, but detailed study of the glacial deposits in these districts might well reveal evidence for the former presence of readvance glaciers of the same age.

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The Pediment Landform : Some Current Problems

By Lester King

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Abstract

The pediment is a widespread and fundamental landform adapted to and moulded by sheet-flow of surface water. The usually abrupt transition from hillslopes to pediments corresponds to a change in surface water flow from linear- to sheet-flow. A cut-rock surface is an essential feature, and where this is buried beneath a detrital mantle some climatic change is to be suspected.

FROM the time of their description by Kirk Bryan in 1922, pediments have appeared periodically in geological literature, generally under the guise of land-features of arid or semi-arid regions. They are, however, not absent from the landscapes of humid regions, and current research indicates that pediments are, indeed, the most widespread and possibly the most important of all land-forms.

Nowadays it is tolerably clear that pediments originate by the parallel retreat of hillslopes behind them. Within any given district whereof the rocks are sensibly homogeneous, the hillslopes often show a remarkably narrow range of declivity, though the hills may differ widely in size and stage of development. This could not be so if the hillslopes, once a stable angle of declivity was attained, had maintained that angle closely throughout their further development. Southern Rhodesia provides many admirable examples of this principle (King, 1949), which is best demonstrated in semi-arid environments. Where the bedrock is not subject to rapid weathering and is of high intrinsic strength, the hillslopes are steep and the contrast between hillslopes and pediment is abrupt (the inselberg landscape) (King, 1949B). Local weathering effects may produce even a nick or overhanging " inverted pediment ", but this is abnormal.

After the pediment has been generated by slope retreat, certain forces act upon it to produce the typical form, a sweeping curve of water erosion from the foot of the hillslope to a near-by stream or river. The modifications produced at this stage (termed pedimentation) are characteristic of sheet-flow on the part of surface water (King, 1949).

The development of landscapes by the twin processes of slope retreat and pedimentation (united as *pediplanation*) is the fundamental mode of landscape development since the Mesozoic, as is exhibited by the physiography of all the continents (King, 1949A). Pediments are limited in extent only by the texture of the drainage pattern, and in declivity only by the lapse of time available before the erosion cycle is distributed and by the potency of the agents of that cycle. But

even to the end, when pediplanation is extreme, pediments still retain a concavity, the concavity of water erosion, and any residuals still rise sharply from the pediment surface.

In all Africa (and with this, data from other continents agree), despite many references, not a single true peneplain exists. All the old-age surfaces—and there are many—are multi-concave pediplains with steep-sided residuals. Parallel scarp retreat and pedimentation have formed them. The South African high veld is a superb example of extreme pediplanation with virtually all its slopes concave. Davis's description of it (1906, pp. 377–480) " The surface has broad swells of very faint convexity between broad depressions of equally faint concavity . . ." is no more than imaginary. Even Mt. Monadnock, prototype of monadnocks, is concave in profile.

Without doubt, all the more ancient landscapes of the globe (Gobi, Africa, etc.) are pediplains and not peneplains (King, 1949A). Their surfaces are multi-concave, not multi-convex. Only when a new cycle causes weak incision of the streams do such plains show *convexity* as in the gently tilted terrains of the Eastern Transvaal around Standerton and Ermelo. Convexity alone is sufficient proof in old-age terrains of two-cycle topography ; and Walther Penck's concept of *endrumpf* and *primärrumpf* is valid. Examples can be quoted from every one of the continental masses, despite W. M. Davis's denial (1932, p. 421). Easily accessible examples for Southern Africa are : for *endrumpf*, the high veld of the Union of South Africa, or the middle and lower Sabi Valley of Southern Rhodesia ; and for *primärrumpf* the landscape west of the railway between Daisyfield and Gwelo, Southern Rhodesia, and many areas in the west of the Union and Bechuanaland.

So the pediment landform, it seems, is very important. It is the fundamental form to which most, if not all, subaerial landscapes tend to be reduced, the world over. This is different from the " Normal Cycle " which one learnt in College days ; but appeal to the world's landscapes leaves no room for doubt : pediplanation, and not peneplanation, provides the keys to the interpretation of continental landscapes.

Thus it has proved possible to map erosion surfaces of an age as great as Mesozoic, because without down-weathering such surfaces survive almost indefinitely (King, 1949, 1949A, 1949C) ; and beyond the seas, it is now feasible to correlate certain landscape cycles from continent to continent (King, 1949A). Peneplanation never did these things ; in fact, with emphasis on down-weathering of hills, it denied the possibility of them.

With pedimentation and pediplanation new weapons have come to the geomorphologist, but before he wields them too heartily it would be well to discover a little more of how they work. The rest of this

study will therefore be devoted to some inquiry into the mechanism of pedimentation.

Of recent years attention has been focused upon pediments as units of the South African landscape. The preponderance of pediments over all other landscape forms has been demonstrated (King, 1947, pp. xvii–xviii), and preliminary inquiry has been made into the mode of origin and development of the pediment form (Fair, 1947, 1948, 1948A ; King, 1949).

Fundamental is the subdivision of the landscape into hillslopes and pediments. These two forms together comprise virtually the whole of the erosional landscape of the African continent. Such clear subdivision over enormous areas, and on many different kinds of rocks, suggests that there is some essential difference in the type of erosional agencies operating on the two forms respectively.

The researches of Fair (1948) have indicated that parallel slope retreat is effected largely by the development of numerous small " gully-heads ". Thus water is dispersed upon hillslopes by thread-flow or linear-flow. But, as the angle of slope falls off, and under the heavy incidence of rainfall typical in Africa, thread-flow soon becomes incapable of removing the volume of precipitation : the threads join up into sheets of flowing water and a land-form is needed which can dispose of sheet-flow. *This land-form, adapted to, and moulded by, sheet-flow of water is the pediment.* It can dispose of the large volume of water produced by a thunderstorm of intensity 3 or 4 inches per hour more efficiently, more quickly, and with less damage to the landscape than any other topographic form : it is the answer to the thunderstorm and the cloudburst.

But pediments need not be confined to regions of rapid precipitation. The hydraulic principles involved apply under more equable regimes when saturation of soil is attained.

Let us examine these hydraulic principles.

Firstly, turbulence is much more generally associated with flow in confined channels than with laminar or sheet-flow, and hence the turbulence associated with the hillslope rills makes them powerful eroding agents and rapid retreat of the hillslopes results.

On the other hand, laminar or sheet-flow across the pediment takes place with a minimum of turbulence and erosion, so that the pediment form is stable and long-lived. Several other reasons conspire towards the same end. Spreading of water in sheets ensures the greatest possible thinness of flow (normally only a small fraction of an inch), and a consequent minimum of turbulence, for turbulence increases for a given velocity with increased depth of flow. Also, with the greater volume of water on pediments as compared with hillslopes (for the pediments must carry the hillslope water as well as their own) there is

greater opportunity for the upper layers of soil to be quickly saturated. When saturation is attained water tends to flow on water, in laminae, so that again turbulence is decreased and erosion minimized.

In the flow of water upon pediments there is thus a reciprocal advantage. A gentle, flat slope of great breadth favours the occurrence of viscous flow in laminae ; and a viscous sheet-flow causes a minimum of erosion and promotes the establishment of a semi-stabilized land-form of low declivity.

Despite the occurrence of vegetation, and especially scattered bushes upon pediments, turbulence seldom is generated thereby. Rather the depressed water surface of viscous flow is usually visible about such obstructions. Herein is a fruitful topic for research by soil conservationists.

Where, however, the sheet-flow is changed by obstruction or channelling into thread-flow, turbulence is immediately created, and the results are disastrous : soils which did not move under laminar flow are swept away, and dongas develop rapidly across the plane of the original pediment. King and Fair (1944) some years ago drew attention to the fact that dongas were typical not so much of steep hillslopes as of relatively flat pediments. In the change from viscous laminar flow to turbulent channellized flow lies the solution of that paradox. The wide, almost universal occurrence of pediments proves the long establishment of conditions appropriate to their formation ; and the fact that so many are scarred by recent dongas shows more clearly than anything else how much interference has been permitted with natural sheet-flow. Clearly, for control of soil erosion in pedimented landscapes, research is needed into the manner of sheet-flow and particularly into methods of preventing sheet-flow from deteriorating into thread-flow. So our gully-scarred pediments insist. None the less, it is interesting to note how many of the recognized, purely empirical methods for control of erosion, such as contour-ploughing and strip-cropping, are really practical applications of the basic principle.

If pediments are a result of sheet-flow, then they should appear best in regions where the *intensity* of precipitation is high, and this is indeed so ; but pediments may appear in any situation where thread- or linear-flow is inadequate to disperse surface water. Thus, towards the foot of slopes in humid climates, where rainfall is much less intense, linear-flow may prove, as the declivity diminishes, inadequate to dispose of the precipitation. This is especially so if the soil is already saturated, when there will be a tendency for " water to flow on water ". At the foot of all slopes, therefore, conditions exist which may lead to pediment formation, and it is significant that in these situations appear the " valley-plain side-strips " recorded by W. M. Davis and which we may class as narrow or incipient pediments.

The fact that the pediment form is governed more by the strenuous conditions of short periods of intense precipitation, rather than by the steadier, long-continued effects of drought or of mild precipitation, is in harmony with other geomorphological phenomena. River channels and shoreline features notoriously owe their formation more to the exaggerated effects of rare floods or storms than to long periods of normal action.

Reduction in the peak incidence of rainfall must produce conditions less favourable to sheet-flow in the landscape. Thus, under a reduced rainfall, or under a more evenly distributed rainfall, thread-flow may be favoured and dongas develop across a previously existing pediment. (The generation of such dongas will doubtless be aided by any reduction in the level of ground-water.)

A further point which has received little attention : the upper surface of existing pediments is often a surface of deposition. Sections displayed in the walls of dongas often reveal from six to ten feet of detritus (transported waste mantle) commonly coarse at the base or throughout. This thickness of mantle is far too great to be moved, even by the greatest floods, and must represent a phase of accumulation. For the mantle rests not upon progressively weathered bedrock but upon a cleanly cut eroded rock surface which, in most instances, is comparatively fresh. Striking, too, is the parallelism between this cut surface and the surface of the ground above, even over whole districts.

Unquestionably, the fundamental feature of the pediment form is the cut-rock surface, whether it is buried or not ; but, as pediments must be reduced ever to lower angles of slope during their existence, the presence over wide areas of such a cover is to some extent anomalous. For the present, some result of climatic change may be suspected. If so the phenomenon will be useful for correlation. Cooke has already remarked how often Middle Stone Age tools are associated with a phase of donga-cutting in the South African landscape.

Conclusion

Pedimented landscapes consist essentially of hillslopes and of pediments. The transition from one to the other is usually abrupt, and corresponds generally to the change in surface water flow from linear-flow to sheet-flow with a corresponding change in character from turbulent to viscous flow. The change takes place relatively suddenly and hence its topographic expression is equally abrupt, separating topographic zones of steepness and low stability from zones of flatness and high stability. Scarps separating cyclic erosion surfaces usually remain juvenile though the topography above and below them is mature or old. The presence of soil upon the pediment also initially reduces

the surface flow by absorption, and, when saturated, produces a tendency for laminar flow of "water upon water" according to established hydraulic principles.

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Kyanite-Gneiss within a Thermal Aureole

By W. S. MacKenzie

(PLATE XII)

Abstract

This preliminary note records two discoveries in the Ross of Mull. Kyanite is considerably more widespread in the Moine rocks than previous investigations have indicated. Where the kyanite-gneiss enters the thermal aureole of the granite, large andalusite paramorphs are formed from kyanite.

THE rocks of the Ross of Mull, Argyllshire, which have been referred to the Moine Series, are bounded on the north-east by the Tertiary plateau lavas and on the west by the Ross of Mull granite. The area was investigated by Bosworth (1910). The present writer is chiefly interested in the development and paragenetic relationships of the three polymorphous forms of Al_2SiO_5—kyanite, andalusite and sillimanite—in the Ross of Mull. The wider geological implications are not within the writer's field of research.

Two separate occurrences of kyanite-gneiss have been described by Bosworth, the mineral being in each case associated with tourmaline. The first is, in Bosworth's words " within a belt of the Moine rocks about 80 yards wide and traceable along the strike for nearly half a mile. The best exposure of this belt is at its northern end, opposite to and about 400 feet south-west from the foot of Loch Assapol in the cliff of the 100 ft. raised beach ". It has now been established that this belt of kyanite-gneiss can be traced almost continuously for two miles along the dominant direction of strike, from Loch Assapol to Ardalanish Bay where it enters the aureole of the Ross of Mull granite as defined by the Geological Survey (Text-fig. 1). (The aureole has not been marked on Sheet 35 but its approximate location has been obtained by continuation of the line marked on Sheet 43.)

The kyanite-gneiss is easily recognizable in the field by the blue crystals of kyanite, averaging about an inch in length, which stand out on the weathered surface of the rock. As might be expected, the mineralogical changes which occur when the kyanite belt enters the aureole are most interesting. Here the gneiss is a beautiful coarsely crystalline rock in which most of the minerals are in a fresh condition (Pl. XII, fig. 1). The blue colour of the kyanite crystals becomes interspersed with pink where they have been transformed into andalusite and particularly fine examples of the association of these two minerals have been developed in quartz-rich segregations (Pl. XII, fig. 2). This transformation is easily seen in the field and the first occurrence of andalusite coincides with the outer limit of the thermal aureole as shown in the accompanying sketch-map.

The formation of andalusite from kyanite as a result of subsequent thermal metamorphism has been described by A. G. MacGregor (1928) from the Lochnagar area in Aberdeenshire and, through the kindness of Dr. MacGregor, the present writer has been able to examine his thin sections superficially. There are some aspects of this occurrence which are different from that of the Ross of Mull : the rock from Aberdeenshire is, in general, finer grained and the relicts of kyanite are relatively small ; while the distribution of andalusite in the Braemar area is not always clearly related to igneous phenomena.

The reverse change has been described by Tilley (1935) in the Carn Chuinneag area (Ross-shire), where kyanite has been developed after chiastolite as a result of the superposition of regional metamorphism on a thermal aureole.

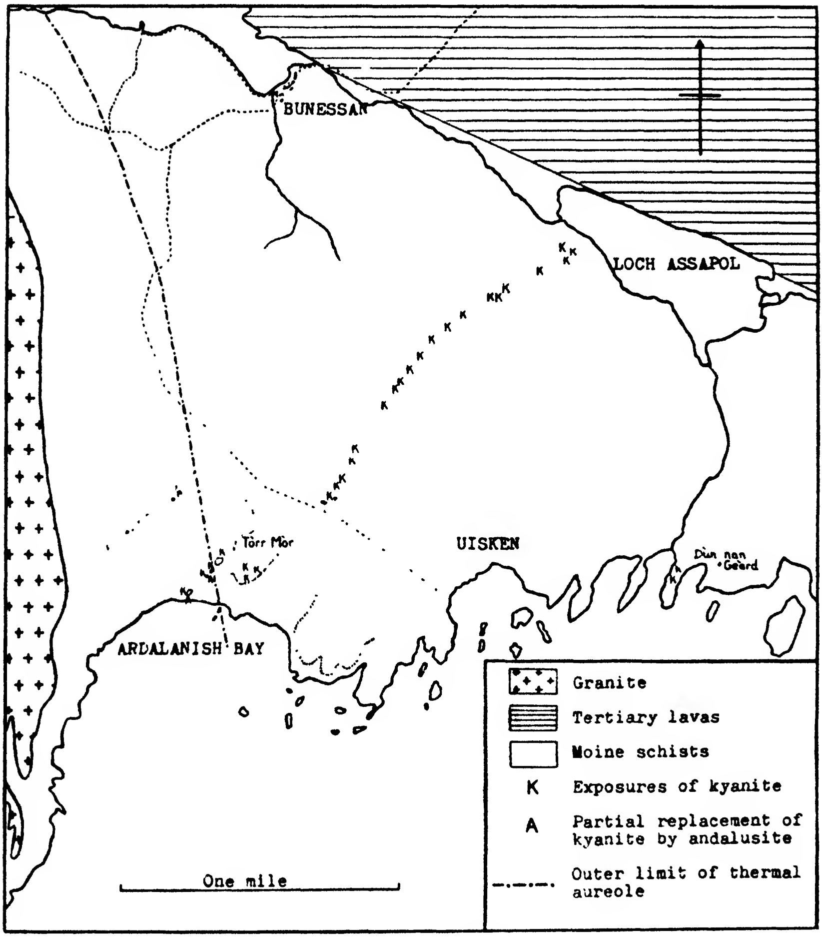
In the Loos-Hamra region of Sweden, von Eckermann (1936) has attributed the replacement of sillimanite by andalusite to thermal readjustment, on approaching a granitic intrusion. From the same area he has described the conversion of andalusite into kyanite as a result of intense shearing stress accompanying faulting of cordierite-andalusite schists.

Erdmannsdörffer (1928) has described two occurrences of the association of kyanite and andalusite. The first, from Lisenz (Tyrol), has been interpreted as kyanite formed by subsequent regional metamorphism of original andalusite, the complete transition from the andalusite to kyanite being seen in thin section. The other occurrence, from Val Calanca (Switzerland), consists of sub-parallel intergrowths of kyanite and andalusite in which the " c " crystallographic axis of the andalusite lies approximately in the (100) plane of kyanite.

In the case of the Ross of Mull occurrence, the andalusite paramorphs do not extinguish uniformly but consist of irregularly oriented grains ; this texture is doubtless due to the increase in specific volume accompanying the inversion. The orientation of several grains of andalusite and of the kyanite which they partly replace, was obtained by means of the Universal Stage and plotted stereographically. No simple crystallographic relationship was found to exist between the two minerals.

In general, the association of these two minerals in the same thin section is rare and the association is even more interesting on account of the fact that intergrowths of andalusite and prismatic sillimanite are found in the pelitic gneiss within the Ross of Mull aureole (Bosworth, 1910). It would be reasonable therefore to expect to find the association andalusite-sillimanite or even kyanite-andalusite-sillimanite where the kyanite band approaches nearer to the margin of the granite on the west side of Ardalanish Bay. So far the writer has been unable to trace the reappearance of this band in this locality.

According to Bosworth (1910) and Clough (1911) an outcrop of kyanite-gneiss occurs intimately associated with amphibolite at a locality on the shore approximately 280 yards west of Dùn nan Geàrd. The kyanite is very localized in development, but crystals can be seen in the field and average about half an inch in length. This rock is



TEXT-FIG. 1.—Sketch-map of part of the Ross of Mull showing the distribution of kyanite.

distinctive on account of the large porphyroblasts of garnet, measuring on an average three-quarters of an inch in diameter, and there is also an abundance of biotite. On field evidence this biotite- and kyanite-rich rock appears to be part of the massive garnetiferous amphibolite within which it occurs and into which it grades. Although both andalusite and sillimanite were detected by Flett, the present writer

has so far been unable to confirm the presence of either of these minerals.

From this brief survey it is clear that there is need of a detailed investigation of the occurrence and relationship of the polymorphous forms of Al_2SiO_5 in the Ross of Mull and this is being undertaken by the writer.

For help in preparing and checking this note in manuscript, the writer is indebted to Professor C. E. Tilley, Dr. H. I. Drever, Dr. E. F. Freundlich and Mr. R. Johnston.

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EXPLANATION OF PLATE

FIG. 1.—Kyanite-gneiss, Dùn Fuinn. × 20. Crossed nicols. The N.W. part of the field consists of a large twinned kyanite porphyroblast with inclusions of tourmaline, rutile and apatite. An andalusite paramorph after kyanite extends from the N.E. to the S.W. corner of the field and it can be seen to consist of elongated and irregularly oriented grains. The dark patch at its N.E. extremity, however, is kyanite with a peculiar "imbricate" structure.

FIG. 2.—Quartz-rich segregation in kyanite-gneiss, Dùn Fuinn. × 20. Ordinary light.

Andalusite enclosing small relicts of kyanite can be seen at the junction of two large kyanite crystals.

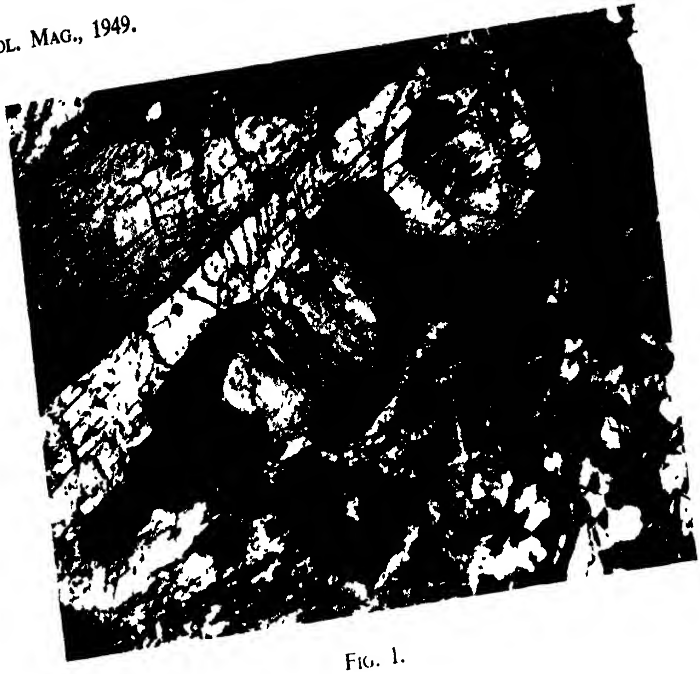


Fig. 1.

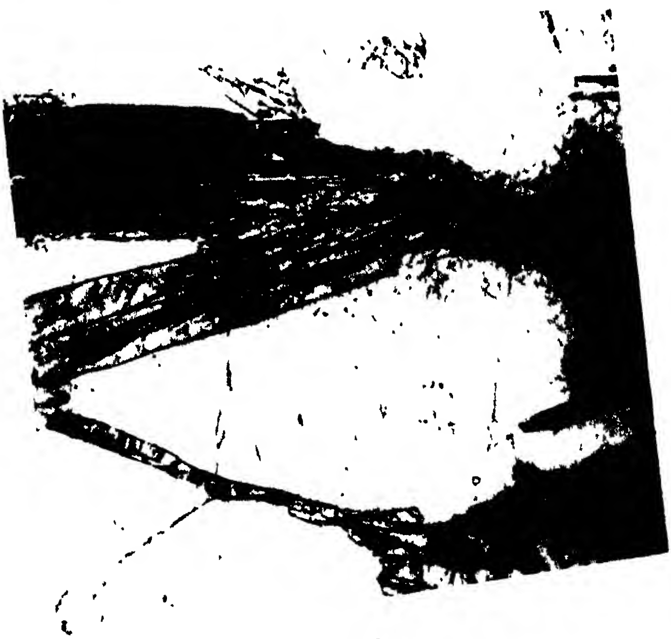


Fig. 2.

The Source of Some Erratics from North-Eastern Northamptonshire and adjacent parts of Huntingdonshire [1]

By P. A. Sabine

Abstract

A collection of erratics from the Boulder Clay and associated remanié drift of the Nene Valley includes distinctive sedimentary, igneous, pyroclastic, and metamorphic rocks. Localities are suggested from which these may have originated and it is concluded that the Upper Chalky Boulder Clay was brought by ice moving from a direction west of north.

During the primary 6 in. survey of New Series Sheet 171 (Kettering) and the adjacent parts of Sheet 172 (Ramsey), a suite of erratics was collected by J. E. Prentice and P. A. Sabine from the area lying to the east of the River Nene in north Northamptonshire and Huntingdonshire, not far from Oundle. The rocks outcropping in this area consist of a very gently dipping series of alternating limestones and clays comprising the Inferior and Great Oolite Series, Cornbrash and Oxford Clay. The limestones form a series of nearly flat plateaux bounded by gentle scarps. The best developed of these plateaux is that formed by the Cornbrash, from which the Oxford Clay has been extensively eroded to form steep slopes, capped by Boulder Clay, some distance back from the edge of the limestone. The Boulder Clay is a gritty grey clay containing abundant chalk both as fragments and as finely disseminated matter. Boulders are abundant, consisting mainly of quartzite of Bunter type, flint, and local rocks including Jurassic limestone and ironstone. Less abundant are boulders of brown sandstone, possibly from the Millstone Grit, and boulders of Carboniferous Limestone. Below the outcrop of the Boulder Clay similar boulders occur in a residual bouldery drift which blankets the slopes of the Oxford Clay, e.g. in the valley of the Billing Brook, south-west of Chesterton. Upon the Cornbrash and lower beds this drift forms a thin pebbly spread until eventually it merges with the river gravels and can no longer be distinguished.

Petrography of the Erratics

The present contribution deals with certain erratics which are so distinctive lithologically as to be easily recognized in the field and to be serviceable as indicator boulders. They have been collected from the Boulder Clay and from the associated remanié drift and include rocks of sedimentary, igneous, pyroclastic, and metamorphic types.

[1] Communicated with the permission of the Director of the Geological Survey and Museum.

Sedimentary Types.—Among those sliced, sedimentary rocks include a greywacke (E. 21241) [1] and a sandstone with tourmalinized cement (E. 21199). The latter is similar to rocks occurring in the Loweswater Flags of Murton Fell, Cumberland. One of the sliced specimens (E. 13244), described in the *Geological Survey Memoir*, " The Geology of the Whitehaven and Workington District " (Eastwood, 1928), compares reasonably well with this erratic, although it contains a somewhat greater quantity of tourmaline ; granulitized quartz forms a larger number of grains ; iron ore is present in smaller quantity, and the tourmaline is more commonly in stout prisms. The greywacke (E. 21241) is a chloritic feldspathic grit with a considerable quantity of carbonate, including calcite and dolomite. The groundmass and quartz and feldspar grains are replaced by the carbonate which often shows well-developed crystal faces. The feldspar includes albite and oligoclase, partially sericitized and perhaps prehnitized. Fragments of shale and grains of iron ore are abundant. This rock resembles the Lower Palaeozoic greywackes of the Southern Uplands, where the calcareous nature of some greywackes has already been remarked upon by Professor W. Q. Kennedy and Professor H. H. Read (1936), and Dr. Malcolm Macgregor (1937). The former authors drew attention to the fact that the carbonate replaced the cement and the clastic quartz and feldspar grains, but in the rocks they described the carbonate did not form well-developed crystals in the cement.

Igneous and Pyroclastic Types.—Igneous rocks include a quartz-dolerite (E. 21242), a porphyrite-breccia (E. 21240), and a granophyric porphyrite (E. 21248). The last-named is composed of phenocrysts of plagioclase set in a holocrystalline groundmass commonly showing granophyric texture and resembles rocks occurring in North Wales, for example the granophyric porphyrite of the Tanycraig Quarry, about ten miles south-south-west of Caernarvon, near Clynnog. The porphyrite-breccia (E. 21240) is an epidotic rock very similar to breccias or agglomerates of Charnwood Forest and compares well with a specimen in the Survey Collection (E. 19171) from the Forest Rock Quarry. The quartz-dolerite (E. 21242), which is of Whin Sill type, is a fine-grained rock consisting of a network of labradorite laths with prisms and stout laths of augite, enstatite, and pigeonite. Alkali feldspar is present, moulded on the labradorite laths, and quartz is interstitial. Iron ore present encloses feldspar and augite.

Pyroclastic rocks are represented by an andesitic tuff (E. 21243) composed mainly of fragments of volcanic rocks together with feldspar, quartz, iron ore, and rare biotite set in a very fine-grained holocrystalline groundmass of feldspar laths cemented by chlorite. This rock may be

[1] Numbers in brackets refer to the English Series of sliced rocks in the Geological Survey collection.

compared with types from the Borrowdale Volcanic Series, for example with the Geological Survey specimen E. 13018 from the north-eastern corner of 1 in. New Series Sheet 37 (Gosforth), to which it bears a fairly close resemblance.

Metamorphic Types.—The collection of erratics also includes some interesting metamorphic rocks. There are two calc-silicate rocks, one a banded epidote, amphibole, garnet, calcic feldspar-granulite (E. 21197) resembling those found in the aureole of the Dartmoor Granite, and the other a scapolite-bearing quartz-hornblende-granulite (E. 21255). Scapolite rocks are not common in Britain but occur in various parts of the Scottish Highlands and in Devon. The erratic resembles the Scottish rather than the Devon types, which are represented in the Survey collection by specimens from Pullabrook and from Walkhampton, south-west of Princetown. These contain a higher proportion of fine-grained material and are more finely foliated than the Scottish rocks.

As metamorphic rocks should also be classed four erratics which are typical of the tourmaline-bearing rocks of the south-west of England. Two of these may be called schorl rock, one (E. 21200) consisting of sheaves of tourmaline up to 6 mm. in length set in a base of interlocking quartz grains, and the other (E. 21254) composed of abundant small radial aggregates of tourmaline set among granular quartz. The other two rocks (E. 21198, 21247) are tourmalinized breccias. These rocks may have been derived from the Midlands Bunter beds, where similar rocks have been recorded by Waller, Bonney, Matley, Dr. J. Phemister, Mr. H. G. Dines, and others. In his researches into the sources of the Bunter pebbles, Matley submitted two tourmaline-bearing specimens from near Birmingham to H. H. Thomas, who reported that they consisted of a schorlaceous breccia and a schorlaceous granite and that it was " hard to assign any other source to these pebbles than the West of England, for in that region alone can the types be matched with any degree of closeness " (Matley, 1914).

More recently Mr. H. G. Dines has recorded (in Richardson, 1946) tourmaline-bearing pebbles from the drift of the Witney District, and these were examined by Dr. J. Phemister, together with specimens collected by Mr. Dines from the Bunter Pebble Beds of South Staffordshire (Phemister, 1936). Regarding the source of these rocks, Dr. Phemister stated that the Staffordshire pebbles were similar to the Witney specimens, some of which strongly resembled the quartz-tourmaline-schist of Roche.

Other erratics, which have insufficiently diagnostic features to suggest any particular locality, include a quartzose sandstone (E. 21202), a fine-grained silica rock (E. 21201), an amygdaloidal trachyte (E. 21249), containing vesicles up to 2 mm. in length filled with granular

quartz, a sheared epidiorite (E. 21251), a hornblende-gneiss (E. 21253), and a garnetiferous hornblende-schist (E. 21257).

Unsliced rocks include one specimen of brown micaceous sandstone, a muscovite pegmatite, a leucocratic microgranite, a foliated quartzite, three specimens of tourmalinized breccia, a dark grey siliceous rock containing veins and blebs of quartz, a muscovite-quartz-schist, and a granular quartz rock having a vitreous lustre and with garnet-rich inclusions containing muscovite and tourmaline.

Directions of Ice-Movements

The drifts of the Nene area suggest that there has been more than one glaciation resulting in a Lower Boulder Clay widely found south of Kettering, overlain by Mid-Glacial gravels followed by Chalky Boulder Clay. The freedom of the Lower Boulder Clay from chalk and flint and the presence of Jurassic and Bunter erratics suggest a derivation from the north along a route lying wholly west of the Lincolnshire Wolds (Hollingworth and Taylor, 1946).

The ice from which the Chalky Boulder Clay has resulted came down the valleys of the Trent and the Witham, receiving additions from the Pennine Ice and from the North Sea Ice. That the chalk of the Chalky Boulder Clay has come largely from Lincolnshire is claimed by Harmer (1928) to be shown by the constant presence and great abundance in the Boulder Clay of grey flint and hard chalk characteristic of that area.

To the east of the Pennines, the present outcrop of the Bunter Pebble Beds occupies a tract of country stretching north from a little east of Nottingham to the vicinity of Doncaster. It therefore seems possible that the abundant Bunter Pebbles of the region here described have been brought from the Trent Basin by ice moving south-eastwards.

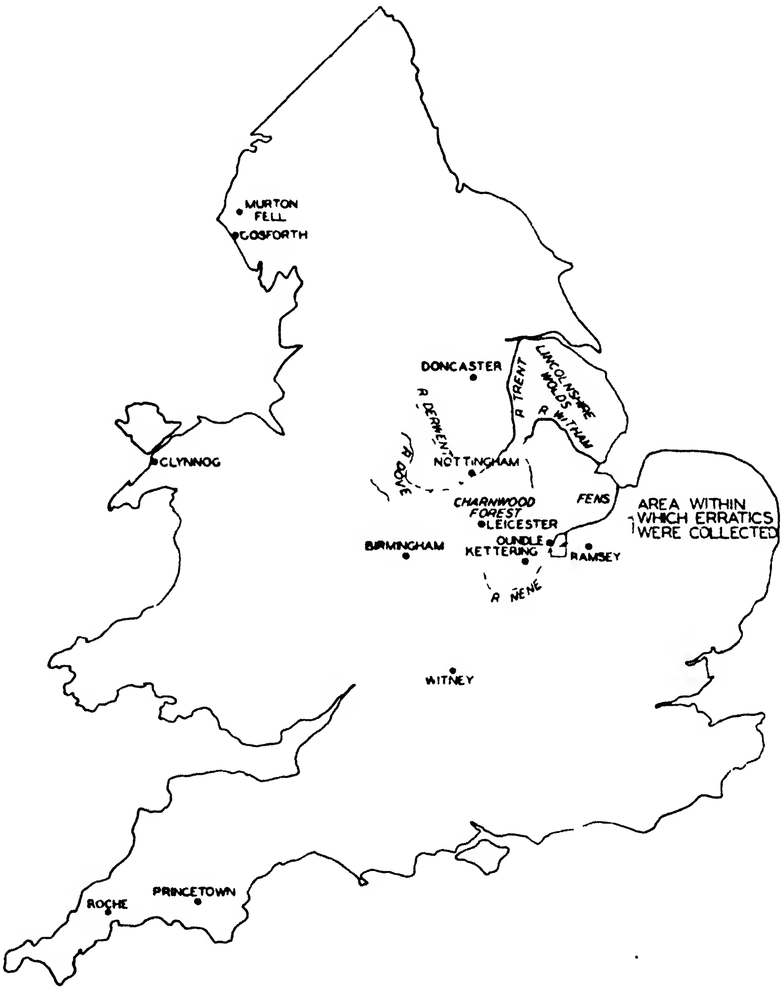
The three erratics suggestive of a Scottish, Lake District, and Whin Sill origin respectively may also have been carried by this ice. Harmer, however, suggests (1928, p. 124) that igneous erratics in the Nene-Ouse basin are derived from beds of Contorted Drift age formerly existing in the Fenland, having come originally from the North Sea.

The tourmaline-bearing rocks and the calc-silicate rock resembling types from the Dartmoor aureole may also have been derived from the Trias by south-easterly moving ice, but until the geography of Triassic time is known more definitely the derivation of these rocks must be regarded with considerable caution.

The erratic of granophyric porphyrite may have been brought east by ice from North Wales and thence by the ice which deposited pre-Chalky Boulder Clay. It is not, however, impossible that this erratic

was derived from the Bunter Pebble Beds deposited in the Midlands in Lower Triassic times.

Evidence for the route by whch the Charnwood rock has reached



TEXT-FIG. 1.—Sketch map showing localities mentioned.

the area is provided by the general distribution of Charnwood erratics, which are found most commonly in the Leicester area to which they have been transported by glaciers moving south-eastwards from the Derwent and Dove valleys. It would appear likely that the erratic now

recorded was brought by this route and was then carried across the Jurassic outcrop by easterly moving ice.

Mr. D. F. W. Baden-Powell has recently suggested (1948A, B) that Upper Chalky Boulder Clay was deposited in eastern England by ice moving in a direction from east of north. In view, however, of the presence in the Upper Chalky Boulder Clay of the Oundle region of abundant Bunter pebbles and of the other erratics described above, the writer is of the opinion that the ice responsible for this boulder clay must have come from distinctly west of north.

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CORRESPONDENCE

PALAEOGEOGRAPHY OF THE MIDLANDS

SIR,—As pointed out in your review of my recent book, *The Palaeogeography of the Midlands*, I there suggested that " the Downtonian and Dittonian are pre-Devonian in age ". I write to beg the indulgence of your pages to make a public confession that I must have had a mental aberration when I wrote this. It is regrettable that the memory of bygone discussions with Mr. Wickham King and carelessness in verifying my statement about the correlation of the beds containing " *Pteraspis dunensis* and other forms with the lowest part of the marine Devonian of the Continent " (I had in mind the Siegenian) should have led me to make this egregious mistake which, I fear, may add to the confusion that has existed over the Siluro-Devonian boundary.

Should a second edition of my book be called for, I shall adopt a classification which would put the whole of the Downtonian into the Devonian, a view which I supported in my *Physiographical Evolution of Britain*.

L. J. WILLS.

THE UNIVERSITY,
EDGBASTON,
BIRMINGHAM, 15.

14th July, 1949.

SALT TECTONICS AND A POSSIBLE IGNEOUS ANALOGY

SIR,—In regions where groups of incompetent rock are interbedded with competent strata, and where large differences of density exist between the two types, crustal disturbance gives rise to rather distinctive tectonic phenomena.

Where the incompetent rock is salt, the structures present are commonly associated under the name of "salt tectonics" and include disharmonic folding, diapiric structures, thrusts, and salt plugs. Salt plugs are frequently large sub-cylindrical masses of salt which either emerge at or approach the surface, having forced their way up by gravity differential. The penetration at the surface is commonly marked by a comparatively sharp, upturned junction without any great disturbance of the surface strata for more than a short distance away from the plug periphery.

When recently considering the probable crustal fore-shortening which appears to have occurred between South Wales and the Brest Peninsula of France, due to the great movements at the end of Carboniferous time, it appeared that this fore-shortening might be in the neighbourhood of 150 miles. The general type of folding rather suggested an analogy with usual salt tectonics of a country like Iran, though on a much larger scale.

It might be possible to consider the Cornish and Devonian granite masses as due to dynamic forces familiar to those giving rise to salt plugs, in which the rise of the masses has been mainly due to the gravity difference existing between the liquid acid magma, and that of the more rigid overburden. Such a viewpoint would suggest a density difference between the overburden and the mean density of the rising magma of something in the neighbourhood of 0·3, with the magma being comparatively light in its molten state when containing its water vapour and gases. To what extent this magma contained sediments melted by depression to great depths during the fore-shortening is not, of course, clear, but this would not be in conflict with the point of view outlined.

With so great a fore-shortening the crustal rocks must suffer very considerable elevation or depression, and as no great elevation is suggested, depression must have taken place, but an estimate of the amount requires very much more knowledge than is at present available as to the position of possible major thrusts developed during these movements. The rather small scale puckering across the Devon peninsula rather suggests the presence of a major thrust underlying these rocks, allowing considerable movement to take place without large scale disturbance of the upper thrust sheet.

While aware of the formidable difficulties in attempting to tidy up such a hypothesis as outlined above, we feel that it might be placed before those interested in such problems for their consideration.

M. W. STRONG.

EAKRING.

7th April, 1949.

THE ORIGIN OF RED SANDSTONES AND CONGLOMERATES

SIR,—I am grateful to Professor Eliot Blackwelder for the information he gave in the March–April number of this magazine about extensive alluvial fans; but on p. 325 of my paper (1948), after citing instances, I said: "These examples of extensive fans show that such fans may have entered into the formation of the New Red Sandstone, but the absence of radial structure makes it doubtful." Owing to unavoidable delay my paper did not appear until long after the completion of the field-work on which it was based, and until after the XVIII International Geological Congress. Between two excursions when I had the privilege of demonstrating the coast-sections of New Red Sandstone in South Devon to our guests, I was able to do more field-work and subsequently deposited with the Geological Survey a chart showing the dips from Broad Sands in the south to the River Exe, also some specimens of boulders with sections, and specimens of structures I found on

Watcombe beach during the first excursion. Of these last Dr. C. J. Stubblefield permits me to quote him as saying that the meniscus-arrangement of rock-particles suggests matter that has passed through the body of an animal, probably an annelid. They are doubtless the annelid tracks mentioned by Ussher and occur in deep red calcareous sandstone about three feet above the Watcombe Clay. Ussher, for some reason I cannot understand, included this rock with the Watcombe Clay, but it is clearly New Red Sandstone. The largest of these specimens I saw measured 14 by 1 inches. Publications show that even larger earthworms are known, but these structures are more likely to have been caused by marine or lacustrine worms on a shore ; and their position close to the Watcombe Clay, which I am now sure is weathered Devonian sedimentary rock, and their apparent absence higher up as far north as Dawlish, suggest that their disappearance was due to the amount of iron in the water.

My difficulty about accepting the alluvial fan origin of the New Red Sandstone of South Devon is that I cannot see convincing evidence of radial dips which ought to be visible in the long, clear coast-sections. Perhaps someone else may succeed where I have failed.

J. B. SCRIVENOR.

68 CHAUCER ROAD,
BEDFORD.
19th June, 1949.

AUTHIGENIC FELSPAR IN FULLER'S EARTH

SIR,—Dr. W. W. Black, in his letter [1] on an Occurrence of Authigenic Felspar and Quartz in Yoredale Limestones, states that he is aware of only one previous record of authigenic felspars in Britain—those described by Reynolds.[2] Another, however, can be mentioned. Newton [3] said that the clean, flaky felspar crystals found in the Jurassic fuller's earth of Combe Hay, near Bath, and the Cretaceous earths of Nutfield and Woburn Sands were almost certainly authigenic. Not only were the optical characters measured, but samples were separated and analysed. Both Nutfield and Combe Hay material, which were similar, suggested the composition of anorthoclase. Brammall and Leech [4] said later that the felspars in the Nutfield fuller's earths were demonstrably authigenic but found that the felspar crop (7·2 per cent in one of the commercial samples) was heterogeneous and the composition variable.

Not only, therefore, have we here records of authigenic felspars in fairly large percentage, but descriptions of authigenic sphene, zircon, and apatite in the Cretaceous earths, and zinc blende, zircon, and apatite in the Jurassic earth.

In all probability these fuller's earths were chemical deposits, like limestone ; under these conditions one may expect minerals beside the main ones to crystallize out. Glauconitic rocks would be expected to yield further examples. The form of the authigenic crystals is of interest in showing some characteristics of incipient crystallization as well as others of well-defined crystallinity.

ROBERT H. S. ROBERTSON.

1 BOTANIC CRESCENT,
GLASGOW, N.W.
28th May, 1949.

[1] BLACK, W. W., 1949. *Geol. Mag.*, lxxxvi, 129.

[2] REYNOLDS, D. L., 1929. Some new occurrences of authigenic potash felspar. *Geol. Mag.*, lxvi, 390.

[3] NEWTON, E. F., 1937. The petrography of some English fuller's earths and the rocks associated with them. *Proc. Geol. Assoc.*, xlviii, 175–197.

[4] BRAMMALL, A., and LEECH, J. G. C., 1940. Montmorillonite in fuller's earth, Nutfield, Surrey. *Geol. Mag.*, lxxvii, 102–112.

REVISED NOMENCLATURE FOR YORKSHIRE ESTUARINE SERIES

SIR,—With the publication of Dr. Hemingway's welcome revision of the nomenclature of the Yorkshire Estuarine Series (*Geol. Mag.*, lxxxvi, 67–71), attention is focused on the inadequacy of a three-fold terminology to describe a four-fold natural division. There is, however, a danger of confusion in that Dr. Hemingway's proposal introduces different stratigraphical limits to his " Middle Deltaic Series " to those previously universally applied to the " Middle Estuarine Series ". The only way of avoiding ambiguity is to apply place-names to all four of the deltaic divisions of the series and accordingly such names are proposed below. At the same time the writer suggests certain other minor modifications, such as the substitution of the word " Beds " for Hemingway's " Sub-Series ".

Fox-Strangways	Hemingway	Sylvester-Bradley (here proposed)
Upper Estuarine Series	Upper Deltaic Series	Scalby Beds
Scarborough or Grey Limestone Series	Grey Limestone Series	Scarborough Beds
Middle Estuarine Series	Gristhorpe Sub-Series (= upper part of Middle Deltaic Series)	Gristhorpe Beds
Millepore Series	Millepore Series	Millepore Series
Upper part of Lower Estuarine Series	Sycarham Sub-Series (= lower part of Middle Deltaic Series)	Sycarham Beds
Eller Beck Bed	Eller Beck Bed	Eller Beck Bed
Lower part of Lower Estuarine Series	Lower Deltaic Series	Hayburn Beds

The two new terms proposed (Scalby Beds and Hayburn Beds) are named after two famous localities for plants in the respective strata.

P. C. SYLVESTER-BRADLEY.

DEPARTMENT OF GEOLOGY,
ST. GEORGE'S SQUARE,
SHEFFIELD, 1.

25th May, 1949.

AN INTERNATIONAL SECRETARIAT FOR SEDIMENTARY PETROLOGY

SIR,—Sedimentary petrologists from twelve different countries held an informal meeting in London last year after the XVIIIth International Geological Congress. As a first step towards the formation of some kind of international organization, it was resolved to set up immediately an International Secretariat for Sedimentary Petrology. Dr. D. J. Doeglas was unanimously elected international secretary.

The Secretariat intends first of all (1) to compile and maintain an up-to-date list of active workers in the subject (addresses, fields, publications, etc.) ;

(2) to compile and maintain a comprehensive bibliography of the subject; and (3) to act as a general bureau for the supply of information, facilitation of contacts between workers, etc.

Sedimentary petrologists are invited to send personal details to:—

Dr. D. J. Doeglas,
Landbouwhogeschool,
Laboratorium voor Mineralogie en Geologie,
Wageningen,
Netherlands

and to make use of the services offered.

A full report of the meeting referred to may be found in *Journ. Sed. Pet.*, 1949, xix, 43–7.

P. Allen.

Sedgwick Museum,
Cambridge.

REVIEWS

A Textbook of Geomorphology. By P. G. Worcester. vii + 584, with 385 text-figures. Van Nostrand Co., Inc. Second Edition, 1948. Price 30*s*.

Few important changes distinguish this volume from the 1939 edition, which has been found one of the more useful elementary geomorphological texts. While primarily designed for the "arts" student as a cultural introduction to the surface of the earth, it serves the geologist with a growing arsenal of geomorphological jargon. Forgetting his own transgressions, he may marvel at the tendency for everyday terms to achieve a technical status, and so graduate from a purely descriptive use to head a paragraph of frequently superfluous definition. However, the author claims to give precise definitions, and succeeds in incorporating these in an attractive book.

W. B. H.

Introduction to Historical Geology. By Raymond C. Moore. McGraw-Hill: London, New York, Toronto, 1949. 8vo, vii + 582, illustrated. Price 30*s*.

Professor Moore aims here at the presentation of earth-history to those having no previous acquaintance with the subject. To achieve his object, he has brought together both an admirable collection of maps, diagrams, photographs, and correlation tables, and a clear, straightforward command of the English language.

In a work intended primarily for the American student, it is not surprising to find much of the stratigraphy falling outside the scope of British elementary courses while hardly reaching the detail needed by the more advanced. Nevertheless, the generous use of photographs, and particularly air-photographs, should appeal to the beginner as showing geology in the grand manner, and advanced students will find here a valuable means of setting detailed successions in a general survey.

From the palaeontologist's viewpoint the main interest lies in the excellent restorations of life-assemblages at various periods, but the short morphological section at the end of the book seems of less value. One would prefer to see, in a mainly stratigraphic work, some indication of outstanding problems and controversies, both to avoid in the reader the impression of a finished work, and to stimulate the application of fresh minds to old discussions.

T. G. M.

GEOLOGICAL MAGAZINE

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The Yorkshire Dogger

IV. ROSEDALE AND FARNDALE

By R. H. RASTALL and J. E. HEMINGWAY

(PLATES XIII–XV)

(*Continued from page 225*)

PETROGRAPHY

Yeovilian

Serpula Sandstone

In parts of Rosedale and Farndale the Serpula Beds are exactly as in Fryup and Danby ; they consist of very fine-grained sandstones or silts, blue, grey, green, yellow, or brown in colour, according to the degree of oxidation, and always full of worm tubes. In many specimens it is clear that practically the whole of the material has been passed through the bodies of worms, leading to a very confused structure. The worm tubes may be several inches long : they are only occasionally vertical or straight, but usually arranged in an irregular manner. Fossils, usually broken and badly preserved, are sporadic, but determinable ammonites of the *striatulum* and *dispansum* zones have been recorded in different parts of the area (Macmillan, 1932, and this paper).

Yeovilian Ironstone, West Gill, Northdale

This was collected from 10 feet below the top of the Serpula Beds and is an example of the developing ferruginous rocks in the highest Yeovilian. It is a dark grey, heavy, fine-grained rock with much mica and many worm tubes, many rather indistinct ooliths and large pebbles up to 1 inch of black, phosphatized, oolitic ironstone. In general terms this is an oolitic siderite-mudstone, but the ratio of ooliths to matrix is very variable, some patches being almost pure siderite. The most notable feature is the distortion of the ooliths, which range from perfect spheres to long streaks in parallel position, giving almost a schistose appearance to the slice. The ooliths show strongly marked concentric structure which can also be traced in the distorted forms. The matrix consists of the usual minute rhombs of siderite, averaging 0·02 mm. long, with conspicuous dark cores : these are set in interstitial kaolinite which is only faintly visible unless stained with basic dyes.

While the foregoing must be regarded as an extreme case, nevertheless in many other places parts of the Yeovilian Series show some approximation to this type, on both sides of Rosedale. Detailed descriptions of these minor variants are hardly necessary.

Chamosite-oolite from Rosedale East Mine (Plates XIII A and XV B)

Specimens from the outcrop show this to be a dense dark grey ironstone with irregularly distributed chamosite ooliths. In the hand specimen it is closely similar to the Middle Lias ironstones of the Eston region, 12 miles to the north. Fossils occur irregularly and are usually preserved as casts or moulds. The micro-structure shows well-formed ooliths, often round in cross-section with good concentric structure and no distortion. The chamosite is of a very pale yellow-green colour and low birefringence. The nuclei where seen are either quartz grains or radial fragments of earlier chamosite ooliths. All the ooliths are slightly corroded and often partially sideritized with well-formed siderite rhombs penetrating their surfaces.

The siderite matrix is clearly of more than one generation. Dominantly it is dark brown and made up mainly of dark cores. Less commonly occurring is a paler, more coarsely crystallized siderite, secondary to the darker variety and sometimes replacing ooliths.

Of the inorganic detrital material quartz and micro-quartzite grains, ill-graded and corroded, are dominant, with only very rare mica and phosphatized grains. Among the organic debris echinoderm fragments are common, usually partly sideritized and chamositized. Many limonite-lined cavities are shell moulds. Altogether organic debris probably calcitic originally made up about 8 per cent of the rock.

Micrometric calculations of the mineral constitution of this ironstone, using a Dollar Micrometer gave the following results :—

	%
Siderite	64·8
Chamosite	25·4
Inorganic detritals	1·7
Organic debris	1·3
Space (mainly moulds of macro-fossils) .	6·6
	99·8

Such a rock would yield 39 per cent metallic iron, which is appreciably more than the usually quoted figure of 32·7 per cent (Fox-Strangways, etc., 1885). Clearly, where sampled at outcrop the rock is richer, presumably more sideritic, than within the mine. This is confirmed by an examination of loose blocks collected near the adits, which were used because of lack of access to the mined area.

One such specimen is microscopically a very fine-grained oolite with few larger elements except a line of large pebbles on one side of the

specimen which is evidently from the top of the ironstone and was probably rejected for that reason. In a slice the rock is very simple, consisting entirely of a close aggregate of small ooliths, with very little matrix. There is no sand and very rare shell chips. The ooliths consist of fresh greenish-yellow chamosite with the usual concentric structure. All are round or oval and not in the least distorted, though a few are broken.

A second loose block is very different, as it contains a large proportion of calcite shells, parts of it being almost shell beds. Ooliths are not very numerous and are irregularly scattered. There is a good deal of mica and a few small pebbles throughout. The microscopic structure is very variable : in parts a fairly normal chamosite-oolite, with siderite matrix ; other patches are very calcareous and shelly and still others nearly pure siderite. This rock is distinguished from all others in Rosedale by the presence of true calcite ooliths with concentric structure. There are few detrital grains except rare pebbles of sandstone with a phosphatized cement, but many shells, shell-chips, and spines, all calcite, with one exception to be described later.

The ooliths are spherical or oval, the majority being pale green fresh chamosite with birefringence exceptionally strong for this mineral, but many are calcite ; some of these may be rolled pebbles of limestone, though their regular shape is against this, while others show concentric structure : in places several neighbouring but separated ooliths extinguish together indicating recrystallization. The matrix is fairly coarse brown siderite with dark cores.

One unusual feature is a complete gastropod of which the shell is now lined with sharp rhombohedra of brown siderite, while the body cavity is filled with a single crystal of calcite which also replaces the shell (see Plate XVB).

Chamositic Rocks from the Hollins Basin.

The lithologies of the Yeovilian at the Magnetite Mines are unusual, as are the field relations.

The green mudstone, which totals nearly 30 feet and which is the lowest bed exposed here, proves microscopically to be heavily weathered and limonitized. It consists of scattered grains of angular quartz silt (maximum diameter 0·1 mm.) with muscovite flakes up to 0·16 mm. set in a matrix which was originally a chamosite mud, but is now weathered. The outstanding feature of this rock is the manner in which small masses of sediment, usually oval in cross-section and up to 3 mm. in length are aggregated in a snowball-like manner in which the mica flakes are orientated circumferentially. Usually the constituent minerals of such aggregates are rather coarser and siltier in grade than the remainder of the rock and this, together with the

mica orientation, causes them to stand out microscopically. The arrangement of the micas also in some fields shows small sigmoidal curves. Clearly, these structures are developed after deposition but before lithification was complete. The pattern of the mica flakes would not support worm action, which results in random flake orientation, but suggests that this structure is micro-slumping, analogous to snowball slumping on a small scale (Fairbridge, 1946).

The overlying Yeovilian oolite (p. 215) shows microscopically abundant ooliths up to 0·6 mm. diameter of warm golden green chamosite slightly limonitized but with good concentric structure. Detrital nuclei are rare. About 25 per cent of the ooliths are well formed. The remainder are distorted to varying degrees, from simple irregularities which simulate unwrapping of the ooliths, through a series of linked forms which culminate in serpentine spastoliths derived from six or more united ooliths (Plate XIV A).

The matrix of the oolite is similar to that of the mudstone, a micaceous and silty chamosite rock, though this is more definitely sideritized. Again, the striking micro-slumping is present, emphasized by the concentrically arranged mica flakes (Plate XIV B). Such snowball aggregates are not confined to the mudstone matrix : at times the mica flakes are orientated around the ooliths, further supporting the view that these latter structures moved after deposition.

The overlying pebble bed in a pasty mudstone matrix shows the process of spastolithization carried to an extreme degree. The ooliths are smeared out into bands giving a schistose appearance and are welded together by a very small amount of interstitial chamosite. Quartz grains are not scattered as is usual, but aggregated into irregular wedges and lenses of quartz sand, very unlike a distribution resulting from normal undisturbed sedimentation. Pebbles up to an inch in length are numerous and well-rounded. They are usually silty and micaceous oolitic ironstones or micaceous grits, but in all cases the matrix is phosphatized to a brown, isotropic collophanite. It is noteworthy that the chamosite ooliths in the altered ironstones are quite undistorted.

From the foregoing it is clear that much of this unusual Yeovilian succession shows evidence of movement during diagenesis. Although these rocks were collected from the flanks of the magnetite-oolite deposits, probably only a few feet from their original extent, it is unlikely that the micro-slumping and spastolithization have any genetic connection with them. It is more probable that such structures arise here by slumping in the generally accepted sense of that term and by a less well-defined settling and sliding towards the middle of the developing and contemporary syncline. It is not suggested that spastoliths were at any stage soft (Pettijohn, 1949, p. 77).

Chamosite-oolite from Sheriff's Pit, Rosedale (Plate 1 B)

Although the evidence for the Yeovilian age of the ironstone is unproved (p. 212), its description is included here because both field evidence and petrographic characters support that conclusion. The rock is macroscopically conspicuously oolitic and in the slice is seen to be composed entirely of close-packed chamosite ooliths up to 0·5 mm. diameter in a matrix of siderite : there is no sand. The only other constituents are a few flakes of twisted white mica and a very occasional phosphatized grain. The ooliths are composed of pale yellowish-green chamosite, very fresh, with concentric structure well developed. Although birefringence is very weak, they give distinct black crosses. Broken ooliths are common and spastolithic distortion is developed. The siderite matrix is coarsely crystalline and colourless when fresh, but the edge of every crystal is oxidized to brown ferric hydrate. Some of the ooliths are extensively sideritized.

The heavy mineral concentrate is remarkable, as it consists almost entirely of dark blue anatase, obviously authigenic, with a mere trace of zircon and rutile. This assemblage has not been seen so strikingly developed elsewhere, though there is an approach to it in Baysdale.

The Ajalon Facies

This facies, which has a wide extension in Rosedale and occurs in Farndale (Blakey Mines), includes a considerable variety of rock types from coarse pebble beds to sandstones of fairly fine grain, variably ferruginous and often oolitic. It is not possible to give detailed descriptions of all these numerous varieties, and a few only of the more striking types will be selected, including especially those which can be matched elsewhere.

West Gill, Northdale

For the most part this is a rather fine-grained blue-grey rock, with distinct current bedding and occasional patches of broken shells and of fine-grained siderite. The proportion of ooliths varies somewhat, being rather higher in some patches of slightly coarser grain. Slices show approximately equal quantities of sand and ooliths in a matrix of siderite. Some ooliths are up to 0·6 mm. diameter and very perfect in shape, but there is every gradation from this to mere lumps and flakes of varying sizes. All consist of perfectly fresh pale green chamosite with fairly high birefringence and very well marked concentric structure. The sand grains are conspicuously angular and well graded, with an average diameter of 0·25 mm. The siderite matrix is rather coarse, with individual crystals up to 0·15 mm. diameter : they are usually cored and slightly oxidized.

There is a close resemblance to a rock from Baysdale, except for the absence of phosphate, probably dahllite, and to rocks exposed in the adits near High Hollins. These rocks, though more oolitic, are also obviously related to the khaki Woodhead Scar facies of Great Fryup (Rastall and Hemingway, 1943, p. 218).

Rosedale Abbey Bank

Macroscopically this is a slightly pebbly oolitic sandstone, dark blue-grey in colour, with many white specks and pale blue ooliths. The many small pebbles are mainly blue-grey mudstone. The matrix is dark grey when fresh and weathers brown.

In the slice small pebbles and sand grains are very abundant. The sand grains are angular to subangular, nearly all quartz, microquartzite

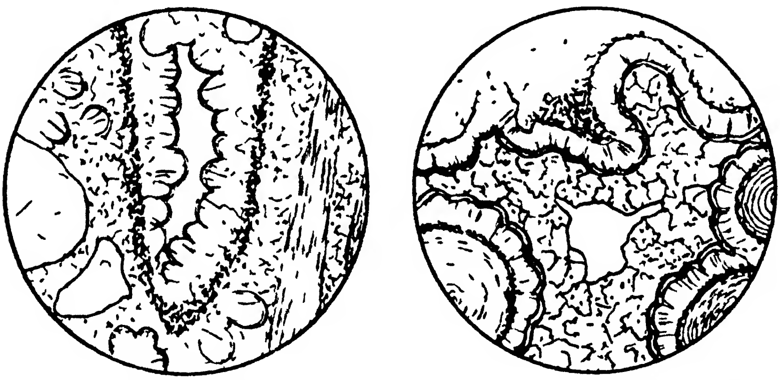
TEXT-FIG. 7.—Speckled oolite of the Ajalon facies, Rosedale Abbey Bank × 45. Chamosite ooliths with detrital quartz, cemented by siderite.

and feldspar being rare. The pebbles are nearly all isotropic, and are phosphatized with replacing collophanite. There is a number of shell and wood fragments. The detrital fragments and mineral grains are not only ill-graded but are irregularly distributed, suggesting fairly rapid deposition. Ooliths are numerous, round or oval, with very sharp margins and not distorted. They consist of pale brown chamosite, very fresh, and with good concentric structure. They vary much in size but rarely exceed 0·45 mm. diameter. There are some broken and irregular fragments of earlier ooliths (Text-fig. 7).

The matrix is entirely different from any other yet seen. It consists partly of siderite so finely crystallized that it gives only aggregate polarization and partly of a mineral which is probably new. This mineral occurs partly as small flakes and groups of flakes disseminated in the siderite and partly as a kind of corona structure, which is best appreciated by reference to the figure (Text-fig. 8). Its general appearance is distinctly chloritic, always with marked fan or

radial structure; colour orange-yellow, with feeble pleochroism; birefringence extremely weak, with negative elongation. The refractive index is almost the same as that of chamosite. There can be no doubt that it is a chlorite, and except for the colour there is considerable resemblance to Hallimond's thuringite (?) in the magnetite-oolite (Hallimond, 1925, p. 25). This mineral does not absorb methylene blue but is slightly stained by safranin, with some pleochroism.

There is considerable textural variation between adjacent parts of this rock in the field. Coarser variants, which are fairly coarse sandstones with pebbles up to 4 mm. in diameter, include numerous chips of pale green cement-stone, and in some layers abundant broken shells and wood fragments. Such rocks, blue-grey when fresh and weathering yellow, show microscopically a moderate number of ooliths, but the greater part of the rock consists of coarse sand in a



TEXT-FIG. 8.—Chloritic corona in part round ooliths Ajalon facies, Rosedale Abbey Bank.

matrix of siderite This is evidently the same as Ajalon rocks at Sandsend, Kettleness, Beck Hole, and Yew Grain, in Great Fryup Head (Rastall and Hemingway, 1940, 1941, 1943), as well as at Blakey Mines.

The microstructure of a fine-grained band is an aggregate of angular sand grains and a few rounded phosphatized grains, with a fairly large but variable proportion of pale green, ill-formed ooliths, ranging into irregular flakes of chamosite, with a matrix of oxidized siderite. Although the macroscopic appearance is different the microscopic character of the finer layers is very similar to that of the Woodhead Scar facies of Great Fryup and strongly supports our association of that facies with the Ajalon facies (Rastall and Hemingway, 1943).

The heavy mineral concentrate shows nothing very distinctive, but the large maximum grade size, poor grading, and the abundance of anatase and brookite, together with a few large brown tourmalines confirm its Ajalon association.

Near Rosedale Abbey Bank the Ajalon facies culminates in typical Black Oolite (p. 215). This rock is very simple in composition (Rastall and Hemingway, 1939) and here consists almost entirely of ooliths in a siderite matrix with very little sand. The ooliths, which are never distorted, but always spherical or ellipsoidal, usually consist of an outer zone slightly stained brown with marked concentric structure, and usually high birefringence (Text-fig. 9). The inner zone is a brown chamosite, probably slightly weathered chamosite of an older generation. The rock is a fairly high grade ironstone with low silica and somewhat calcareous, but unfortunately is of only limited development.

The Hollins Basin

The Dogger, near Kitching's deposit, is a typical example of the coarser varieties of the Ajalon facies. Macroscopically it is a coarse-grained gritty rock, fairly well bedded with visible wood fragments, a variable proportion of pale blue ooliths and small pebbles in a red weathering matrix. The microstructure is very variable, the chief constituents being sand, chamosite, wood, and shell fragments in a siderite matrix. The abundant sand grains vary much in size and shape and include a good deal of perthitic felspar. The chamosite is partly in the form of well-formed ooliths, but owing to distortion it shows every gradation to shapeless patches, nearly all of which, however, still show some degree of concentric structure. The colour is pale green and the birefringence extremely weak. The matrix consists of rhombs up to 0·06 mm. in diameter, now considerably oxidized, and they also replace parts of the ooliths. This same sandy oolite may be traced to the most southerly extent of the Dogger in Rosedale (p. 216) without lithological change.

The heavy mineral concentrates are large and red, characterized by great abundance of brookite in several habits. Anatase, in sharp pyramids, is rather scarce, and some specimens show a little pink garnet and red sphalerite. The two last named minerals are very characteristic of the Ajalon facies of the western area of north-east Yorkshire. No magnetite was detected.

This rock is too siliceous for a workable ironstone, though apparently attempts have been made to mine it. It is similar lithologically to rocks previously described from Kettleness, Beckhole, and Fryup (Rastall and Hemingway, 1940, 1941, 1943).

Blakey Mines, Farndale

This attempt to work the Ajalon facies for ironstone was foredoomed to failure, for although the section shows a remarkably fine development of these rocks, they are too siliceous and phosphatic to be of economic value. Black Oolite, similar to Rosedale Abbey Bank is developed here, but the greater part is closely related lithologically

to rocks of Ajalon facies in Great Fryup and south-east Rosedale, though with some special features of their own. The texture of much of the rock is coarse, almost a fine conglomerate in places. Most specimens contain a fair number of ooliths, difficult to see macroscopically except when separated by solution of the matrix in acid, when they are jet black (i.e. typical Black Oolite facies).

The micro-structure is complicated and hard to describe shortly. The chief constituents are sand, pebbles, and ooliths, shell chips being rare (Text-fig. 10). The pebbles are fine sandstones and chamosite-ooliths with the matrix replaced by brown collophanite. An unusual feature is occasional small pebbles of phosphate rock with dahllite in flat plates. These are pebbles of mudstone replaced by collophanite which has recrystallized to dahllite. Sand grains are dominant, varying much in size and up to 2 mm. in length : the larger are moderately

TEXT-FIG. 9.—Black Oolite, Rosedale Abbey Bank. × 45. Stained ooliths in a siderite cement.

TEXT-FIG. 10.—Black Oolite, Blakey Mines, Farndale. Stained ooliths and phosphate pebbles in a coarsely crystalline siderite matrix.

rounded, the smaller angular and deeply corroded. The ooliths vary much in diameter to a maximum of 0·5 mm. and in nearly all the concentric structure is very conspicuous. A few ooliths are double, two partly developed individuals being enclosed in a single outer envelope. The matrix consists of pale brown, very fresh siderite in crystals up to 0·65 mm. long, but not poecilitic, as in the better developed Black Oolites of Sandsend and Great Fryup (Rastall and Hemingway, 1939). It is this recrystallized siderite which gives the crystalline appearance to the hand specimen.

Magnetite-Oolite, Rosedale (Plate XV A)

Only loose blocks of this rock may now be found, usually blue-black in colour and slightly oxidized. These specimens show some mineralogical variation and suggest that the original deposit was not

uniform. One type, apparently more common, shows many well-formed ooliths up to 0·6 mm. diameter, made up of pale green chamosite invaded with magnetite along the cleavage planes. The magnetite is in the form of vast numbers of octahedra from ·002 mm. to ·012 mm. in length, but usually nearer the smaller figure ; these form thin zones which alternate with the chamosite, but which sometimes fuse to form a thicker layer. There is no uniformity in the degree of magnetite formation, which in adjacent ooliths may vary from a thin surface layer to almost complete replacement. Irregular radial cracks, formed by volume reduction during magnetitization are common in the ooliths and these are now filled with a chlorite or a carbonate. Some ooliths show evidence of crushing after magnetitization, probably also consequent upon volume reduction. The nuclei are oolite fragments, unmagnetitized collophanite grains, and brown irregularly limonitized grains of doubtful origin.

The cement was originally a chloritic mineral, chamosite in part, which may now be magnetitized, but which is largely replaced by large poikilitic plates of siderite with a vague radial arrangement. Some ooliths are heavily carbonated with both broad concentric bands or irregular patches of siderite, while in extreme cases an oolith may be entirely replaced with siderite leaving only a magnetite rim.

A second, less common type is characterized by the complete absence of carbonate minerals. The ooliths are either converted to magnetite or concentrically zoned with alternating magnetite and chamosite. The nucleus is a warm golden brown chlorite, very finely crystallized and only weakly birefringent, usually giving only mass polarization effects. The matrix is entirely chloritic, fairly coarsely crystalline, with rouleux and vermiform aggregates. Some of this is chamosite, but a pale yellow chlorite with strong pleochroism and higher birefringence is also present.

A conspicuous feature of all slices examined is the absence of detrital grains. In this the Rosedale magnetite-oolite is unlike any of the Inferior Oolite ironstones of this region and more closely related to those of Yeovilian age.

The green mineral described by Hallimond (1925, p. 75) is seen in a slice of an oxidized specimen, where it consists of hexagonal plates separated by layers of some yellow mineral, like a honeycomb. As these structures are seen only with a quarter-inch objective, the nature of the minerals concerned has not been determined. The matrix of the fresh specimen also encloses flakes of a blue-green chloritic mineral which Hallimond identifies as thuringite (?). The colour is more blue than any chamosite known to us, and the pleochroism and birefringence stronger. A somewhat similar mineral, but orange brown, is described on p. 271.

It is hoped to examine the chlorites in this rock in detail at a future time, and it is sufficient now to confirm Hallimond's determinations, and mention some others, emphasizing that the chlorites are, in the main, different from what has been met with elsewhere in this investigation.

Our best thanks are given to Dr. L. R. Cox and Dr. L. F. Spath, of the British Museum (Natural History), for the identification of fossils quoted in this paper : to Mr. W. Anderson, of the Geological Survey, for assistance with mine and bore-hole records ; and to Mrs. E. F. Dickins for permission to quote from the log of the Crosscliff bore.

Conclusions

1. The tracing of the beds of the Lias-Oolite junction in north-east Yorkshire has been continued southwards into Farndale and Rosedale, where the distribution and succession follow, in the main, those of upper Eskdale. The Yeovilian strata are separated from the Dogger (s.l.) of the earlier writers (Fox-Strangways, Reid, and Barrow, 1885 ; Lamplugh, 1920, etc.). The term Dogger (s.s.) is restricted to those marine beds at the base of the Inferior Oolite of Yorkshire. In the area under consideration they rest unconformably upon several horizons in the Upper Lias and they underlie the Lower Deltaic Series.

2. On field evidence the low-grade ironstones (chamosite-siderite oolites) once worked at Rosedale East Mines and Sheriff's Pit and hitherto regarded as of Dogger (Inferior Oolite) age, are shown to be late Yeovilian age (*dispansum* or post-*dispansum*). These rocks are unknown elsewhere in Yorkshire. Lithologically, the ironstone from Rosedale East Mines is closely similar to Middle Lias ironstones of the Cleveland ironstone field further north.

3. The original boundaries of the sedimentational basin of the Rosedale ironstone did not extend far beyond the present limits of Rosedale. To the northern part of the dale pebble beds at this horizon indicate shallows where no ironstone was laid down, while the increasing proportion of detrital grains in the ironstones of southern Rosedale probably indicate a shore line in that direction. The ironstone thus represents the final depositional phase in the silted-up Liassic sea.

4. The two worked ironstones are now preserved in two of the several shallow, elongate tectonic basins of Caledonoid trend and pre-Dogger age. It appears probable that the structural basins, with their complementary anticlines were forming during the deposition of the ironstones, because the preservation of the thick wedge of Yeovilian chamosite-mudstone in the Hollins Basin could only result from downfolding during deposition. Further, the lithological

individuality of each of the ironstones suggests that each was precipitated in an area which was developing its own facies characteristics, though not necessarily completely separated from the other ironstones. The rising anticlines may well have provided such partial barriers.

Other similar but shallower structural basins are found in other parts of Rosedale, as well as Farndale and Great Fryup, and although these hold ironstones they are not of economic value. What was originally believed to be a single north–south pre-Dogger structural basin occupying the Fryup, Danbydale, Rosedale, and parts of adjacent dales is demonstrated to be a series of Caledonoid folds mainly arranged *en echelon* along a north–south line. Yeovilian rocks are now proved to occupy more than 55 square miles in this part of Yorkshire.

5. Ironstone pebbles, subsequently phosphatized, were eroded from the crests of pre-Dogger anticlines which separated the depositional basin into smaller structural basins; these pebbles contributed to the basal pebble bed of the Dogger (Inferior Oolite), together with other phosphatized Liassic calc-mudstones.

6. Marley's field evidence concerning the distribution of the Rosedale magnetite-oolite is reconsidered. The oolite is accepted as filling two channels cut in the Liassic surface, which pre-date at least a part and probably all the Dogger. This oolite is not believed to be contemporaneous with the Bilsdale channel fillings.

7. The Dogger (s.s.) rests unconformably upon truncated Yeovilian and Whitbian rocks and the Rosedale magnetite-oolite.

8. The marine Rosedale Sandstone is defined. Its distribution suggests that the downwarping over the ironstone basin continued into Inferior Oolite times.

9. The Black Shales continue south from upper Eskdale as the most valuable mapping horizon in the Dogger. These shales are now grouped as a part of the Blakey Series.

10. Facies variation is recognized in the main sandstone of the Dogger, which is here named, with the underlying Black Shales, the Blakey Series. The Green Flags, the Woodhead Scar sandstone, the Ajalon Series, etc., hitherto regarded as successive beds, are recognized only as facies variants of the upper part of the Blakey Series.

The distribution of these facies suggests that shallow water lay over Northdale, where the pebbly and ill-graded Ajalon facies was deposited. Deeper water lay to the west and north-west, where finer-grained, well-bedded, and well-graded rocks were laid down.

11. The petrography of the outstanding rock types is described. Micro-slumping and spastolithization are common in some of the oolitic ironstones and are regarded as evidence of contemporaneous

deformation of the sediments. Subsequent magnetitization in the magnetite-oolite is recognized, as well as the much commoner sideritization of the ooliths and detrital constituents of all the ironstones. The importance of siderite in all the rocks of the Lias-Oolite junction in this region is emphasized.

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PLATE XIII

A.—Photomicrograph of chamosite-oolite, Rosedale East Mines, Rosedale, Yorkshire, × 40. Chamosite ooliths with fair to poor concentric structure, all showing corrosion and incipient sideritization. The matrix is finely crystalline siderite, slightly limonitized. The whiter areas are shell moulds.

B.—Photomicrograph of chamosite-oolite, crags near adit to Sheriff's Pit, Rosedale, × 40. Chamosite ooliths (grey) showing spastolithization and sideritization. The matrix is coarsely crystalline siderite (white), now part limonitized (black).

PLATE XIV

A.—Photomicrograph of chamosite-oolite, north wall of Kitching's Deposit, 600 yards W.N.W. of High Hollins Farm, Rosedale, × 40. Chamosite ooliths (grey) with good concentric structure, showing the development of spastoliths in several stages. The matrix is a sideritized chamosite mudstone, limonitized (black) by recent weathering, with quartz-mica silt.

B.—The same, showing micro-slumping in the oolite-free fraction of the sediment.

PLATE XV

A.—Photomicrograph of magnetite-oolite. Loose block near Kitching's deposit, Rosedale, × 40. Magnetite-chamosite-carbonate ooliths in which magnetite (black) alternates with chamosite and carbonates. The carbonates may be in optical continuity with the matrix.

B.—Photomicrograph of chamosite-oolite, loose block near Rosedale East Mines, Rosedale, × 24. Siderite rhombs (grey) line the inner wall of a gastropod shell and fill its apex. A single crystal of calcite infills and replaces the shell. Limonitized siderite forms the matrix of the ironstone.

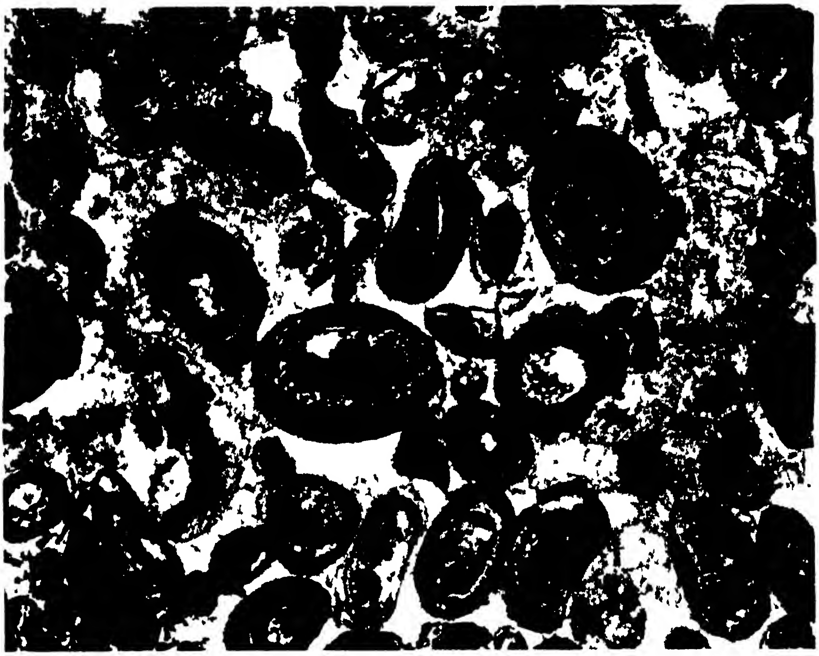
B

PHOTOMICROGRAPHS OF ROSEDALE IRONSTONES.

A

B

PHOTOMICROGRAPHS OF SPASTOLITHS AND MICROSLUMPING IN YEOVILIAN IRONSTONE, ROSEDALE, YORKSHIRE.



PHOTOMICROGRAPH OF MAGNETITE-OOLITE, ROSEDALE

B

PHOTOMICROGRAPH OF GASTROPOD IN EAST MINES IRONSTONE, ROSEDALE.

Lineation in Moinian and Lewisian Rocks of the Northern Highlands of Scotland

By F. C. PHILLIPS

(PLATES XVI AND XVII)

ABSTRACT

It has recently been reaffirmed, on the basis of evidence derived from published maps, that in the Moine schists the south-easterly plunging lineation appears to increase in intensity as the Moine thrust area is approached. This statement is not in accordance with facts observable in the field and is a false premise on which to base the conclusion that thrusting and lineation are related. A further fact of vital significance in relation to such a conclusion is the widespread development of a similar lineation, plunging south-easterly and likewise expressive of a girdle fabric, in unmoved Lewisian rocks of the foreland.

STUDY of the structural petrology of the Moine schists has established that a girdle fabric is of widespread occurrence throughout this metamorphic assemblage. Muscovite and biotite are commonly orientated in simple girdles of varying degrees of completeness, whilst quartz diagrams show either a simple girdle or intermediate types transitional to a well-developed two-girdle arrangement (Phillips, 1937, 1945). The axis of the girdle is commonly marked by a megascopic lineation, mainly defined by the orientated arrangement and elongated habit of the micas. Over wide areas, this lineation plunges in a south-easterly direction. Though controversy at present centres around the genetic interpretation to be placed upon this lineation and its associated grain-fabric, the facts summarized in this paragraph are probably not questioned by any petrologist familiar with the rocks of the Northern Highlands.

A valuable contribution to the study of lineation in general is afforded by a recent memoir by E. Cloos (1946), a publication for which all structural petrologists will be grateful. An annotated bibliography covering a period of over a century is appended to a critical review which displays clearly the complexity of some of the problems involved. In the course of this review, several references are made to the distribution and possible significance of lineation in the Scottish Highlands. Progress must be founded upon a basis of established facts, and it is because I believe that some of the statements in this review are not in accord with present factual knowledge that I wish to comment upon them.

On p. 3 it is stated that " In Scotland lineation is well known as ' rodding ' . . . and is shown in maps and described from many localities. Its intensity appears to increase generally as the Moine thrust area is approached ". In Plate 9, a map of the Assynt region is reproduced from parts of 1 in. map-sheets 101, 102, 107, and 108.

Commenting on this map, the author writes " Most of the lineation symbols are near the thrust planes and mostly in the area of crushed rock " (p. 27), and " Lineation is most pronounced in the vicinity of the thrust planes " (p. 28). At first sight, it may well appear that the published 1 in. sheets support such a generalization; whilst there are many lineation symbols on such sheets as 114, 108, 101, 102, 92, and 82 covering the area adjacent to the outcrop of the thrust, there are none at all on sheets such as 115, 109, or 83 to the east.

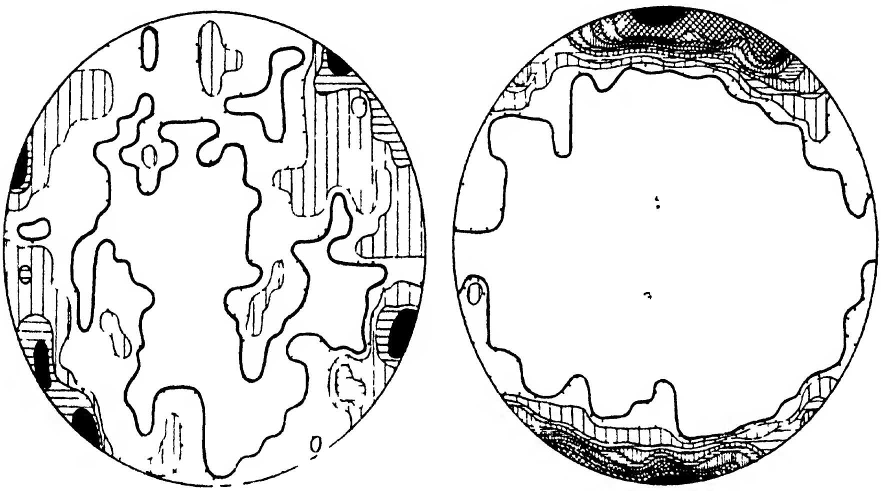
This distribution of symbols on the published maps, however, unfortunately does not afford an entirely reliable guide, since the absence of symbols from particular sheets does not mean that lineation cannot be observed in these areas in the field. Whilst some of the surveyors, notably C. T. Clough and those who were trained under him, were fully alive to the importance of this feature (see, for example, the many careful descriptions of linear structures in the memoir on sheet 93, The Geology of Ben Wyvis, etc., 1912, in a series of paragraphs all over the initials C. T. C.), others mapped only the strike and dip of the schistosity. On sheet 82 there are many symbols, on the adjacent sheet 83 to the east none at all. At various times I have examined the Moinian rocks over wide areas, from Fair-aird Head and Bettyhill in the north, southwards to the Great Glen, and to Sleat in Skye. Excluding material from the areas occupied by injection-complexes, a clear lineation is visible in about two-thirds of the specimens collected; in a random sample of fifty specimens, covering a range from psammitic rocks with very little mica to highly pelitic types, thirty-two show a lineation sufficiently marked to be used in orientating thin sections cut from the hand-specimen. Good examples can be studied in the field at the following localities selected because they lie at distances between 20 and 35 miles east of the outcrop of the Moine thrust :—

East side of Loch Shin, north-west of Lairg, sheet 102.
Between Bonar Bridge and Invershin, sheet 102.
In the Blackwater river, near Garve, sheet 93.
West of Struy, Strath Glass, sheet 83.
North of Invermoriston, west side of Loch Ness (sheet 73, unpublished).

It is, of course, well known that a lineation of similar type to that under discussion is also developed extensively south of the Great Glen (see, for example, Anderson, 1948), both in rocks generally correlated with the Moinian and in members of the Dalradian assemblage. The problems here, however, are more complex, involving for example the development in places of a superposed lineation of different type, and the area will be excluded from the present account. Even with this exclusion, I do not believe that the facts of the distribution of lineation throughout the Moinian support the

generalization that lineation increases in intensity towards the outcrop of the thrust. The arguments advanced by Cloos " Thus the general conclusion seems justified that these structure elements are due to north-westward movement along thrust planes " (1946, p. 3), and " This (distribution of lineation symbols) indicates that thrusting and lineation are related, and, if thrusting is towards the north-west, the lineation in that direction is closely related to that movement " (p. 27) appear to be based on false premises.

Thus far, reference has been made only to rocks mapped as belonging to the Moinian assemblage. Rocks assigned to the Lewisian occur mainly in the foreland region, on the mainland north-west of the outcrop of the Moine thrust and in the Outer Hebrides, as a complex



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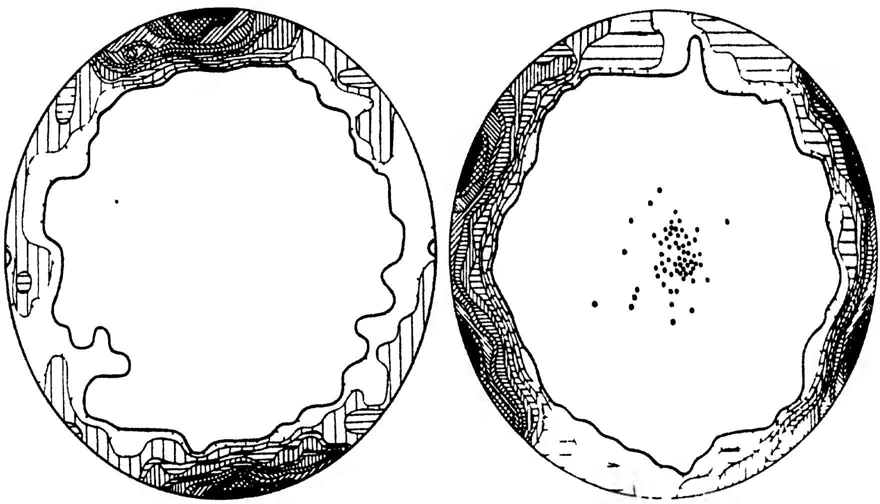
TEXT-FIG. 1.—Biotite-epidote-oligoclase gneiss, ⅛ mile north-west of Laxford Bridge. 250 quartz. Max.. 4%.

TEXT-FIG. 2.—250 biotite in same slide as Text-fig. 1. Max. : 14%.

largely composed of orthogneisses but including also some paragneisses and paraschists. This fundamental complex is cut by a series of intrusions, and is unconformably overlain in places by Torridonian and Cambrian sediments. South-east of the thrust, rocks mapped as Lewisian are found both as overthrust masses within the belt of complication (Peach and Horne, 1930, p. 46), and also as supposed " inliers " within the Moine area. The peculiar relationships revealed in places by the mapping have caused doubt to be cast upon the validity of the factors used in separating supposed Lewisian from Moinian rocks in some areas (Read, 1934, pp. 312, 316), and in Central Sutherland at least no evidence of discordance between rocks of Lewisian type and the Moine Series could be detected (Read, 1931,

p. 69). In Morar, Richey and Kennedy (1939) considered that they could distinguish a structurally lower group, separated from the Moinian rocks by a line of discordance, which they named provisionally Sub-Moinian. It has recently been suggested, however (MacGregor. 1948), that the factors on which this separation was based are invalid, and that the Sub-Moine rocks of Morar may constitute a lower part of the Moine Series associated with hornblendic orthogneisses. In view of these present obscurities, the term " Lewisian " in the account which follows is to be understood merely to imply rocks so coloured on the published maps. Examination of such map-sheets as 107,



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TEXT-FIG. 3.—Hornblende-biotite gneiss, 1 mile north-east of Lochinver. 250 biotite. Max.: 14%.

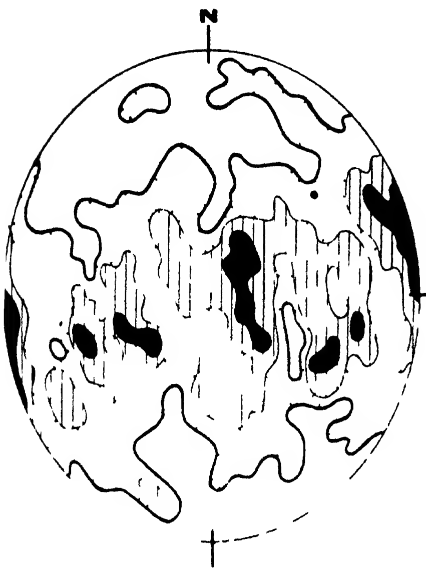
TEXT-FIG. 4.—Hornblende-schist, 1½ miles south-east of the summit of Slioch. 126 prismatic cleavages of hornblende and 63 corresponding z-axes. Max.: 12%.

101, 92, and 91 will at once reveal that a lineation, sufficiently pronounced to attract attention in the field, is present in many Lewisian rocks. Indeed, nearly fifty symbols which lie within the Lewisian of the foreland structurally below unmoved Torridonian, and not within the area occupied by Moinian rocks, are shown in Cloos' reproduction, pl. 9. With few exceptions, these symbols show a south-easterly plunge, and examination in the field has confirmed that, over a wide area of the foreland and also in rocks mapped as displaced Lewisian masses and in some at least of the supposed inliers, a south-easterly plunging lineation is a characteristic feature of the fabric.

As already briefly stated (Phillips, 1947), measurements on orientated sections have proved that in these rocks, as in the Moine schists, the

direction of lineation is normal to a girdle of the grain-fabric. Girdles are shown by all the readily measurable component minerals of the fabric, such as quartz, muscovite, biotite, and hornblende, in rock types varying from granitic gneisses to hornblende-plagioclase gneisses and hornblende schists. That such fabrics prevail may, indeed, be deduced from the remarkable descriptions published by Teall over forty years ago. Of the Loch Maree mica-schists he wrote (Peach and Horne, 1907, pp. 75–6) :

" The flat surfaces of schistosity possess a silky lustre and show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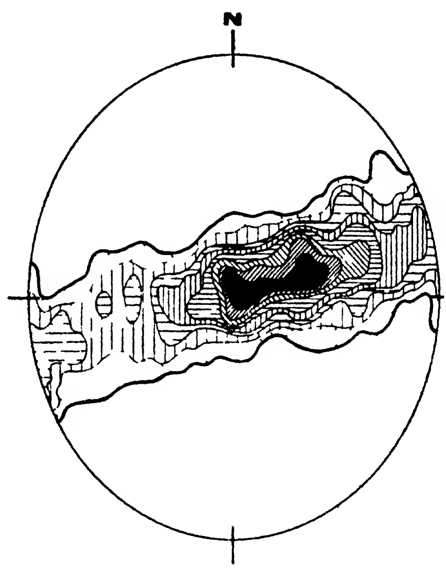
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TEXT-FIG. 5.—Biotite-epidote gneiss, Meall an Spardain. 300 quartz. Max : 3%.

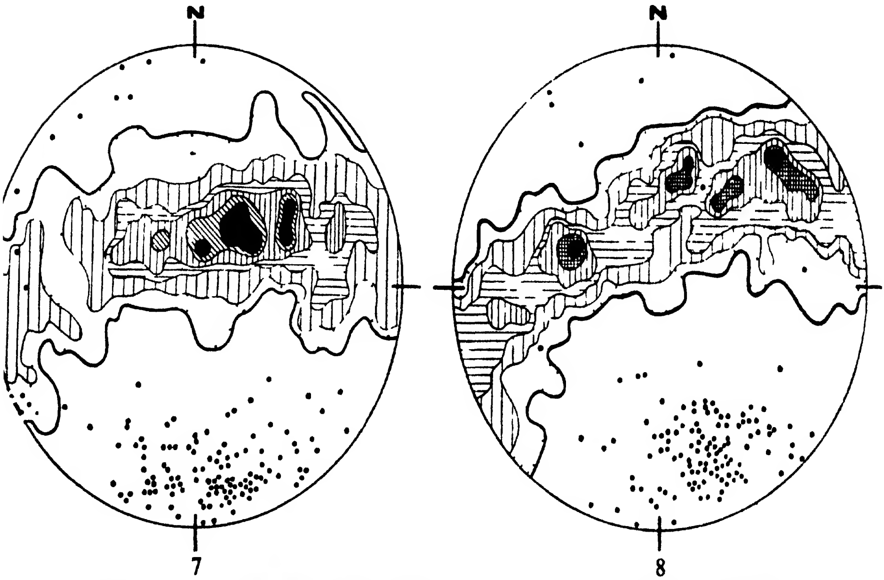
TEXT-FIG. 6.—250 biotite in same slide as Text-fig 5. Max. : 8%.

a fine parallel striping .... The individuals of quartz are irregular in outline and variable in size ... a slight tendency to flattening in the direction of schistosity and elongation in the direction of striping may be observed. In microscopic structure there is a marked contrast between the section at right angles to the schistosity and parallel to the striping, and that at right angles to the schistosity, and also at right angles to the striping. The former shows a perfect parallel structure due to the arrangement of the mica-flakes ; the latter shows the mica-flakes lying at all angles and gives unmistakeable evidence of minute puckering."

In quartz-magnetite rocks he observed the positions of maximum

and minimum illumination in quartz aggregates between crossed nicols. Of the Poolewe district he wrote (p. 97):

"Near the centre of the district, south of Poolewe, in which Mr. Clough has proved the existence of a kind of anticlinal structure in the arrangement of the dyke-like masses, the hornblende schist is linearly foliated, parallel with the pitch of the folds. This is well seen in a specimen from a point five-eighths of a mile north of Meall an Spardain. The rock is essentially composed of green hornblende



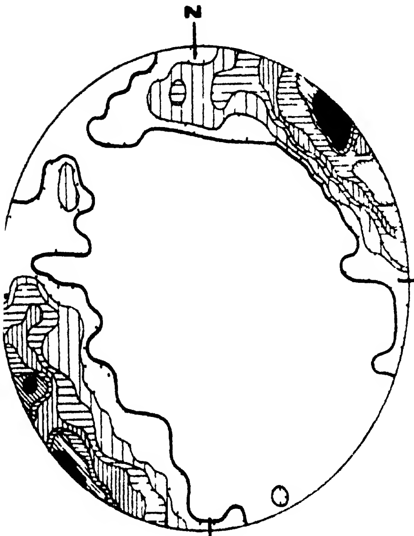
TEXT-FIG. 7.—Hornblende gneiss, Meall an Spardain. 250 prismatic cleavages of hornblende and 125 corresponding z-axes. Max.: 6%.

TEXT-FIG. 8.—Hornblende gneiss same locality as Text-fig. 7. 250 prismatic cleavages of hornblende and 125 corresponding z-axes. Max.: 6%.

and a somewhat basic oligoclase. Quartz and a few grains of colourless sphene are also present. Two sections have been prepared; one parallel to the direction of foliation, the other transverse (Pl. XLIX, Figs. 1 and 2). A comparison of the two shows that the individuals of hornblende, though irregular in outline, are arranged with their vertical axes approximately parallel with the direction of foliation, and consequently with the pitch of the folds in the district. The grains of oligoclase are irregular in outline and of approximately equal dimensions in the different directions. The rock has not been subjected to mechanical deformation since the formation of the existing minerals. There are no signs of cataclastic action. These facts prove that the rock was either intruded during movement and consolidated in its present form, or that a previously

formed rock was entirely recrystallized under the influence of the stresses which produced the 'rodded' or 'mullion-structure' of the district."

Text-figs. 1–4 are examples illustrating the results of measurements on sections cut normal to a megascopic lineation, in specimens from localities scattered between Loch Laxford in the north and Gairloch some 50 miles south-south-west. The attitude of the girdles in space, corresponding to the predominating south-easterly plunge of the



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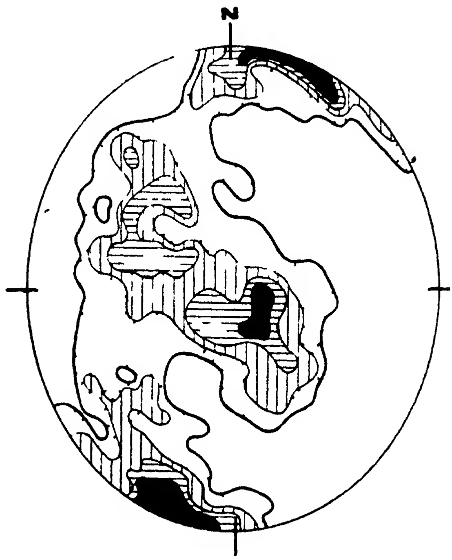


10

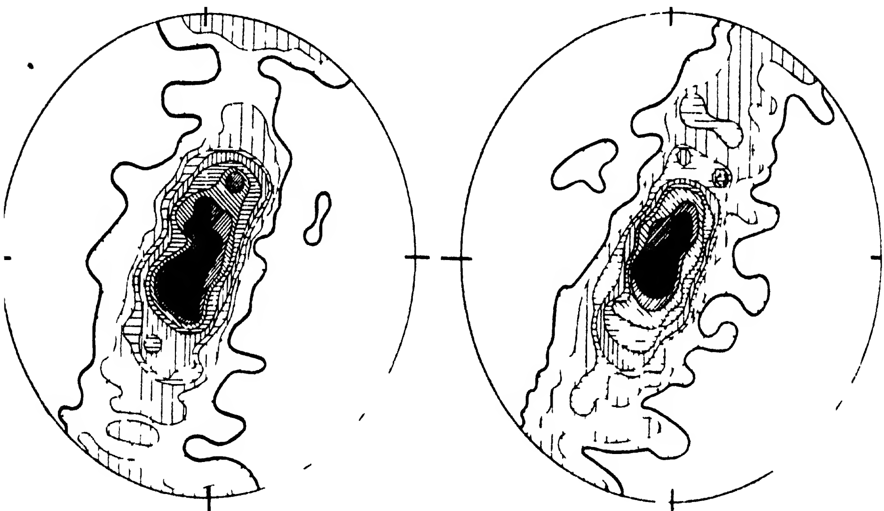
TEXT-FIG. 9.—Muscovite-biotite gneiss, ½ mile north-north-east of Lochinver. 250 muscovite. Max.: 8%.

TEXT-FIG. 10.—Muscovite-biotite-epidote gneiss, Knock Bay, Sleat, Skye. 207 quartz. Max.: 4%.

lineation, can be appreciated most readily from diagrams rotated to their true geographical orientation. Text-figs. 5–9 illustrate in this manner a further selection of measurements. Text-figs. 10–12 provide an example of the closely similar conditions prevailing in rocks mapped as displaced Lewisian within the overthrust region above the Moine thrust in Sleat, Skye; the micas occupy well-defined girdles, but it is of interest to note that the quartz diagram shows an incipient development of a second girdle, a feature which, where it is developed in Moinian rocks, I have tentatively related to overprinting (Phillips, 1945, p. 218).

These diagrams and descriptions thus show that an argument which seeks a direct correlation between the distribution of lineation in Moinian rocks and the outcrops of the overthrusts is still further

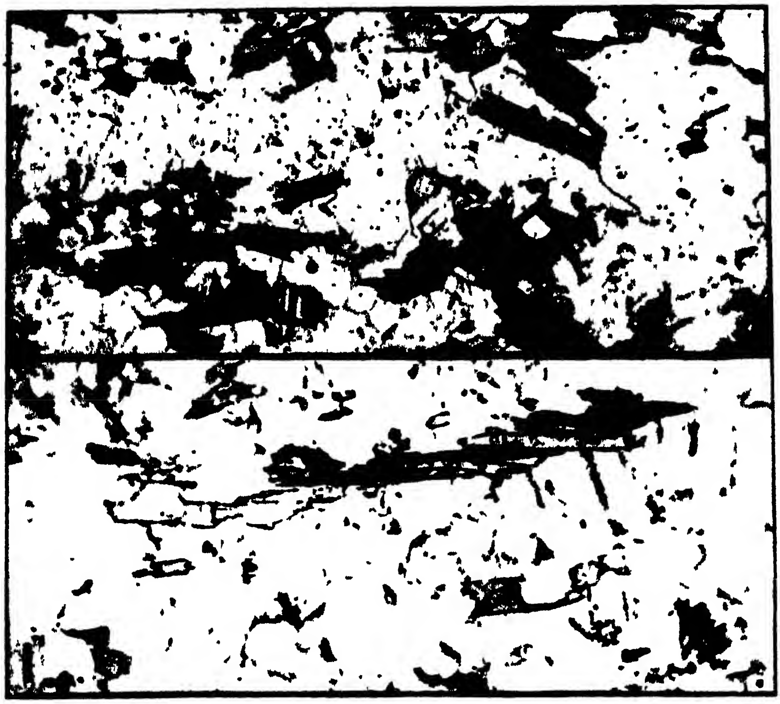
weakened by the widespread development of a closely similar lineation in Lewisian rocks, both of the foreland and in displaced masses. The purpose of this communication is to place these facts on record, without proceeding at this stage to further consideration of possible genetic interpretations of the lineation and associated fabric. For that reason I have refrained from using descriptive terms, such as *a*- and *b*-lineations and B-tectonites, to which genetic significance is now attached in the literature of structural petrology. Even, however, if the validity should eventually be established of the sweeping conclusion reached by Anderson (1948, p. 125) that "a rather fundamental mistake has



11 12

TEXT-FIG. 11.—250 muscovite in same slide as Text-fig. 10. Max.: 10%.
TEXT-FIG. 12.—250 biotite in same slide as Text-figs. 10 and 11. Max : 10%.

hitherto usually been made in the interpretation of petrofabric structures", and lineation of this type should be proved to be always parallel to direction of shear (" direction of transport "), the problem presented by the close resemblance between the fabrics of Moinian and of Lewisian rocks still calls for solution. I am unable meanwhile to follow the argument put forward by Shackleton in support of his suggestion (discussion on Anderson, 1948, p. 128) that the lineation in the Lewisian foreland is parallel to the direction of pre-Cambrian movements—an interval of approximately 10^9 years between pre-Cambrian and Caledonian orogenies does not seem to me so short as to justify the statement that " the whole system of movements *suddenly* changed their direction through a right angle ".



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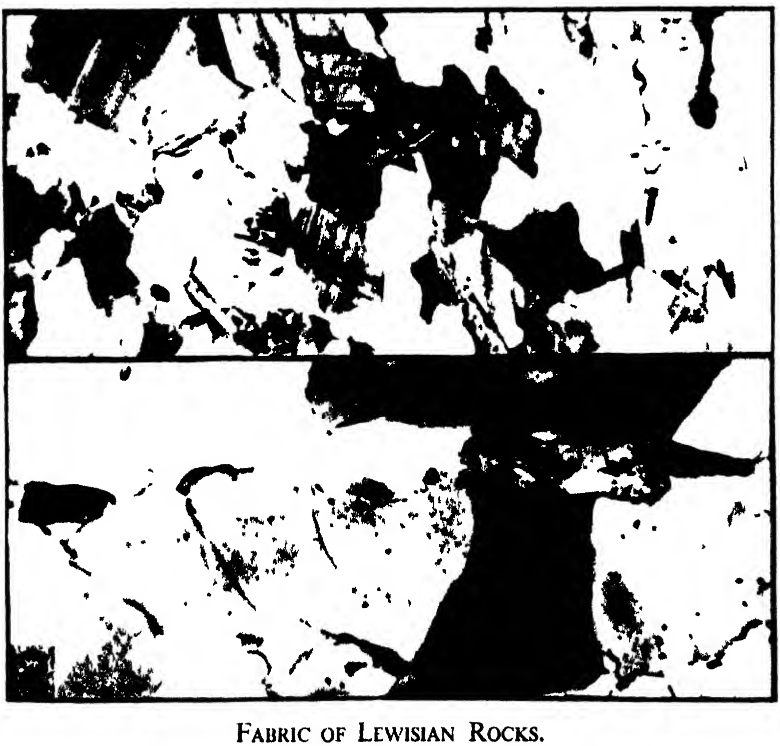
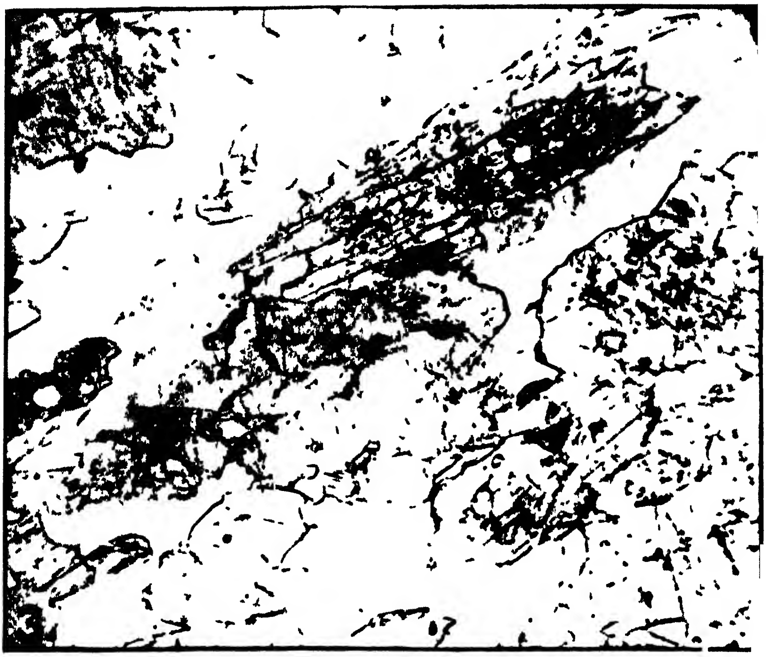


2

FABRIC OF LEWISIAN ROCKS.



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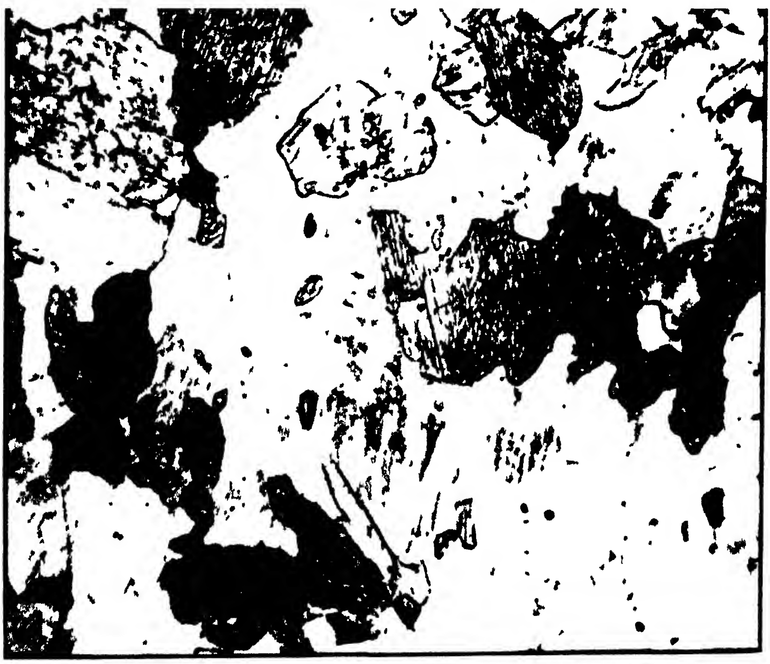

2

FABRIC OF LEWISIAN ROCKS.

Nor is a solution to be found by postulating a late recrystallization and reorientation of the quartz, the fabric of which would thus be related only to the " latest phases of dislocation . . . only a component of the entire movement and not representative " (Cloos, 1946, p. 28 ; compare also Tilley, discussion on Phillips, 1937, p. 619, and on Anderson, 1948, p. 129). The problem presented by the Moinian and Lewisian rocks alike is that of a fabric essentially homotactic in respect of all the essential minerals—quartz, muscovite, biotite, hornblende. With the possible exception of certain minor features, (Phillips, 1945, p. 215) it is the whole metamorphic fabric of these rocks which is involved. Though the facts ascertained may be awkward in relation to some particular tectonic synthesis, it is our task to explain these facts and not merely to explain them away.

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EXPLANATION OF PLATES

PLATE XVI

Textures of Lewisian rocks. × 18.

In each figure the upper strip is from a section normal to the lineation and the lower from a section parallel to the lineation.

FIG. 1.—Biotite-epidote-oligoclase gneiss, ½ mile north-west of Laxford Bridge. Polarizer only.

FIG. 2.—Feldspathic gneiss with biotite and epidote, Meall an Spardain. Crossed nicols. The section parallel to the lineation shows the grain elongation in quartzose bands.

PLATE XVII

Textures of Lewisian rocks. × 18.

FIG. 3.—Hornblendic gneiss, 2½ miles north-east of Gairloch. Section normal to the lineation.

FIG. 4.—Same rock as Fig. 3, section parallel to the lineation.

The Age of Uraninite and Monazite from the Post-Delhi Pegmatites of Rajputana

By ARTHUR HOLMES (*University of Edinburgh*)

With Chemical Analyses by A. A. SMALES (*I.C.I. Research Dept., Billingham, Co. Durham*), and Isotopic Analyses of Lead by W. T. LELAND and A. O. NIER (*University of Minnesota, Minneapolis, U.S.A.*)

ABSTRACT

Uraninite and monazite collected by Dr. H. Crookshank from pegmatites occurring respectively at Bisundni and Soniana (Rajputana) have been analysed for U, Th, and Pb by Mr. A. A. Smales, and the isotopic constitution of the lead separated from each mineral has been determined by Dr. W. T. Leland and Prof. A. O. Nier. The three ages calculated from the uraninite ratios AcD/RaG, RaG/U and AcD/U are 740, 733, and 733 m.y. The monazite is considerably altered but the corresponding ratios indicate that its age lies between 700 and 865 m.y., which is consistent with the more reliable estimate determined from the uraninite. It is shown from tectonic evidence that the Delhi orogenic belt is younger than the Satpura belt (previously dated at about 900 m.y.) and that both are younger than the Aravalli and Dharwar belts.

I. INTRODUCTION

THREE years ago I heard that a small pocket of uraninite had been discovered in a pegmatite occurring in Rajputana. Realizing the importance of this find from the point of view of dating one of the best known Pre-Cambrian orogenic belts of India, I addressed an inquiry to Dr. W. D. West, Director of the Geological Survey of India, and suggested that the age of the uraninite should be determined. Dr. West at once sent me some samples of the uraninite, together with several large fragments of monazite crystals from another pegmatite of the same suite, and at the same time he put me in touch with Dr. H. Crookshank who had discovered and collected the minerals. I then approached Dr. R. Holroyd, Research Manager of Imperial Chemical Industries, Limited, Billingham Division, who, after consultation with Mr. W. C. Hughes, Chief Analyst of the Research Department at Billingham, commissioned Mr. A. A. Smales to undertake analyses of the two minerals for uranium, thorium, and lead. In each case Mr. Smales also prepared samples of lead—in the form of carefully purified lead iodide—for transmission to Professor A. O. Nier, who in the meantime had agreed to determine the isotopic constitutions of the two leads. It is a pleasure to express here my thanks to all these gentlemen for their willing and generous co-operation in this work. My own share has been to organize the joint investigation, to calculate the ages and discuss their significance in relation to Pre-Cambrian geology and, with the exception of Sections VI and VII, to write the paper.

II. Geological Setting

The Aravalli ranges, which cross Rajputana from Delhi to Gujerat in a general N.E.–S.W. direction, consist essentially of a synclinorium of more or less metamorphosed rocks belonging to the Delhi and Aravalli Systems. In certain localities the Raialo Series occurs between the two systems with unconformable junctions above and below. The Aravalli basal conglomerates lie unconformably on a gneissic complex, the more granitic parts of which are commonly correlated with the Bundelkhand " Gneiss " of the type area to the east. The general sequence is as follows (Coulson, 1933 ; Gupta, 1934 ; Heron, 1935 ; Krishnan, 1943) :—

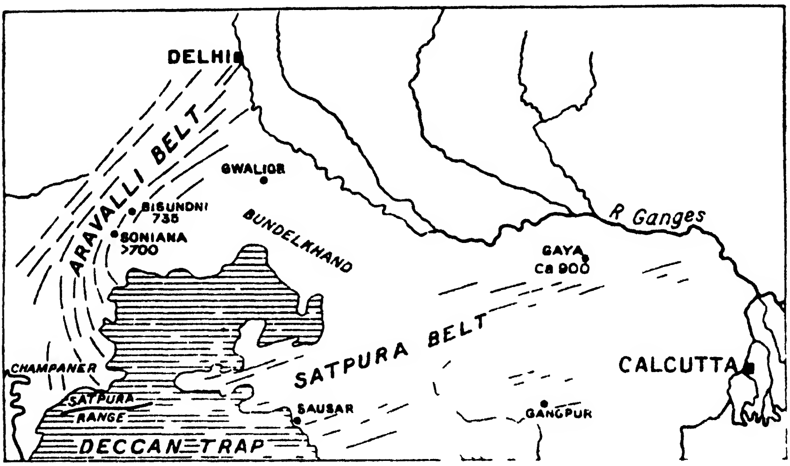
	Pegmatites, aplites, and quartz veins.	
	Granites (e.g. the Erinpura Granite).	
Delhi System	Dolerites, epidiorites, and hornblende-schists.	
	Ajabgahr Series.	and metamorphic equivalents.
	Calcareous and argillaceous beds	
	Alwar Series.	
	Quartzites and arkosic grits	
	Raialo Series.	
	Schists, marbles, and quartzites.	
Aravalli System	Dolerites and epidiorites.	
	Pegmatites, aplites, and quartz veins.	
	Granites and migmatites.	
	Epidiorites, hornblende-schists, and serpentine-chlorite-rocks	
	Shales, limestones, quartzites	and metamorphic equivalents.
	Quartzites and grits	
	Local basic volcanics	
Gneissic Complex	Pegmatites, aplites, and quartz veins.	
	Granites and migmatites.	
	Paragneisses, amphibolites, and chlorite-biotite-schists.	

Three orogenic cycles appear to be represented in Rajputana, the Raialo Series, which is only about 2,000 feet thick, being probably part of the third, i.e. the Delhi cycle.

(i) The *Gneissic Complex* and the Bundelkhand granite and gneiss may possibly represent more than one cycle, as the various parts, exposed between successive belts of the Aravalli and Delhi rocks, have not as yet been satisfactorily correlated. As a whole, however, the complex has a N. or N.N.W. trend and it clearly forms a deeply denuded basement on which the later formations were deposited.

(ii) The *Aravalli Orogenic Belt* swings round in the south and follows a N.S. trend in the " Champaner Series " which has now been correlated with the Aravallis by continuous mapping (cf. Text-fig. 1). Further east the trend gradually changes to a N.N.W.–

S.S.E. direction as the Deccan trap is approached. This direction would carry the Aravalli Belt into the Dharwars which appear on the southern side of the Deccan traps. It is therefore tempting to correlate the Aravallis with the Dharwars. However, it is equally possible that the Gneissic Complex may be, or may include, a correlative of the Dharwar cycle, and until appropriate radioactive age determinations have been made, all such suggestions remain purely speculative. It is interesting to notice, however, that the ancient rocks of the Satpura Range, which rise above the present surface of the Deccan traps, have a roughly E.-W. trend, which implies that they cut across the Aravalli Belt and are therefore younger. These Satpura rocks are regarded



TEXT-FIG. 1.—Map showing the dominant trend lines of Pre-Cambrian orogenic belts in the northern part of Peninsular India. Numbers refer to the ages (in millions of years) of dated radioactive minerals.

as a continuation of the Sausar and Gangpur Series of the vast Pre-Cambrian area lying to the east of the northern part of the Deccan traps.

(iii) The *Delhi Orogenic Belt*, in the area under consideration, is superimposed on the Aravalli belt and has the same regional trend (see map in Heron, 1935). Further west, however, the Delhi rocks do not share in the southward turn of the Aravallis but appear to continue straight on towards Kathiawar (cf. Krishnan, 1943, p. 139). As a test of the continental drift hypothesis it will be of great interest to see if continuations of the Delhi and Satpura belts can eventually be recognized on the other side of the Arabian Sea. In India the Delhi and Satpura belts fail to meet and their relative ages cannot be determined geologically. The evidence from radioactive minerals presented in this

paper indicates, however, that the Delhi is the younger. See p. 298 for further discussion.

Each of the three orogenic cycles of Rajputana ends with a display of pegmatites and, since the younger pegmatites also occur in the older rocks, it is not always easy to assign its proper age to any particular occurrence. Pegmatites known to be of pre-Delhi age are medium-grained and often foliated and disturbed by later movements; they are characteristically lacking in accessory minerals other than occasional flakes of muscovite. Most of these older pegmatites appear to be of post-Aravalli age, but some undoubtedly belong to the Gneissic Complex, since they have contributed to the basal conglomerates of the Aravalli (Coulson, 1933, p. 18). The post-Delhi pegmatites are coarse-grained, massive and unfoliated rocks which often carry considerable quantities of muscovite and tourmaline and sometimes of apatite and beryl. They vary in form from small lenses a few feet wide up to massive dykes which may be as much as a hundred feet across and a thousand feet long. They generally dip steeply at 70° or 80° and, though rare in the Alwar quartzites, they are commonly found in the mica-schists of the Ajabgarh Series (Heath, 1947). Exactly similar pegmatites also occur in the phyllites and mica-schists of the Aravalli System. Mica-rich pegmatites of this kind are distributed along a broad belt stretching from Gujerat to Delhi; many of them are worked for mica, or have been in the past, and until recently some of them were also worked for beryl (Crookshank, 1947, pp. 4–5). Being obviously later than the regional metamorphism that has affected the Delhi schists and quartzites, this whole suite of pegmatites is regarded as of post-Delhi age.

The uraninite and monazite discovered by Dr. Crookshank were both found in pegmatites belonging to the post-Delhi suite. The occurrences will be described in detail by Dr. Crookshank in a forthcoming paper.

III. The Uraninite and its Age

The uraninite was collected from a large pegmatite occurring in biotite-gneiss at Bisundni, Ajmer-Merwara (25° 44′; 75° 9′ 30″). The pegmatite has been opened up for muscovite and beryl and is still being actively worked for mica. The uraninite and its associates occur in nodular masses in association with beryl and cleavelandite. The largest of the specimens sent by Dr. West from Dr. Crookshank's collection contains several black lustrous cores of uraninite up to 2 cm. or more across, surrounded by coalescing aureoles of bright red to yellowish red gummite (5–6 mm. wide) followed in turn by broader shells of up to 15 mm. across of dull yellow uranophane associated with a canary-yellow material that may be becquerelite or shoepite.

The boundaries between the black cores and the red and yellow zones appear to be sharp, but in thin section a rapid gradation of colour is seen. The canary-yellow mineral sends long veinlets of acicular crystals into the surrounding cleavelandite, which has clearly been metasomatically replaced. A few micaceous scales of autunite are embedded in the yellow shells. One specimen, which is part of a pseudomorph after feldspar, has a violet-coloured mineral (instead of gummite) between the uraninite and the uranophane ; this mineral resembles ianthinite (Shoep, 1927) but it has not yet been identified with certainty. In some of the smaller specimens the uraninite cores have almost disappeared and the yellow zone has widened at the expense of the red, indicating progressive replacement. There is nothing to suggest that the alteration is due to weathering. The massive appearance of the material and its replacement of feldspar suggest that it represents a late stage of alteration in the history of the pegmatite itself.

The uraninite cores of the largest specimen are seen in thin section to be perfectly fresh and free from fractures and veinlets. The cores from one half of the specimen were broken out and crushed into small pieces. Lustrous fragments free from adhering crusts of gummite were picked out and prepared for the analysis made by Mr. Smales (see p. 299). The lead isolated during the analysis was conveertd into pure lead iodide for transmission to Professor Nier. The results of the isotopic analysis carried out by Leland and Nier are recorded in Table I.

TABLE I

URANINITE, BISUNDNI, AJMER-MERWARA, RAJPUTANA, INDIA

Chemical Analysis (A. A. Smales) :

Pb	U	Th	$\frac{Pb}{U+Th}$	$\frac{U}{U+Th}$	*Apparent Age (m.y.)*
7·95	72·9	1·4	·107	·98	730

Isotopic Analysis of Lead (W. T. Leland and A. O. Nier) :

Isotopic Proportions	Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
In Total Lead . .	$<$·001	100·00	6·39	·806
In Original Lead . .	(negligible)			
Per cent of Radiogenic Lead in Uraninite.		7·416 RaG	·474 AcD	·06 ThD
	$\frac{AcD}{RaG}$	$\frac{RaG}{U}$	$\frac{AcD}{U}$	$\frac{ThD}{Th}$
Ratios	·0639	·1017	·0065	·0429
Apparent Ages (m.y.) .	740	733	733	935

It will be seen that the uraninite is unusually poor in thorium. The crude age read from the family of graphs prepared by Wickman (1944) is 730 million years. The isotopic constitution of the lead is stated in proportions relative to Pb^{206} taken as 100. Since the proportion of Pb^{204} is less than ·001, it follows that the uraninite is practically

free from original lead, of which Pb^{204} (not being of radiogenic origin) is an index. Pb^{206} thus represents RaG, the end product of U^{238}; similarly, Pb^{207} represents AcD, the end product of U^{235}; and Pb^{208} represents ThD, the end product of Th^{232}. The " age " of the mineral, t_m, can be calculated independently from each of the three ratios RaG/U, AcD/U, and ThD/Th. The respective equations (Keevil, 1939) are :

$$t_m = 15\cdot15 \times 10^9 \log_{10}(1 + 1\cdot158\,\mathrm{RaG/U})\ \text{years.}$$
$$t_m = 2\cdot37 \times 10^9 \log_{10}(1 + 159\cdot6\,\mathrm{AcD/U})\ \text{years.}$$
$$t_m = 46\cdot20 \times 10^9 \log_{10}(1 + 1\cdot116\,\mathrm{ThD/Th})\ \text{years,}$$

where the chemical symbols represent the percentages of the parent elements and of the isotopes of radiogenic lead now present in the mineral. A fourth value for t_m is given by the ratio AcD/RaG. This cannot be directly calculated from the ratio, but Wickman (1939) has calculated the values of the ratio for values of t_m up to 3,500 m.y. and has expressed the results graphically, so that, knowing the ratio, the value of t_m can be read off. If a mineral has remained unaltered, all four values for t_m should be in close agreement. For reasons that at present are not fully understood—though the extreme difficulty of determining Th with accuracy is certainly one of them—the " age " calculated from ThD/Th almost invariably differs considerably from the most probable age. The present example is no exception to this rule and, as usual, one can only set aside this particular age-value as being unreliable. The ages from RaG/U and AcD/U, however, are found to be in perfect agreement (733 m.y.). In such a case the age from AcD/RaG should theoretically also be identical and, indeed, the value actually read from Wickman's diagram (740 m.y.) differs no more than is to be expected in practice. Amongst old minerals such perfection as this is rare, the only comparable case being that of a uraninite from Ontario (Holmes, 1948*a*, p. 183). It is clear that the Bisundni uraninite is of exceptionally good quality as an index of age, and the age now assigned to it—735 ± 5 m.y.—may be given a place amongst the very few that can be accepted as of first-class reliability.

IV. The Monazite and its " Age "

The monazite was collected from a pegmatite at Soniana, Mewar State (25° 7′; 74° 40′), that was formerly worked for mica. This locality is marked on a geological map by Gupta (1934). The uraninite locality is about 50 miles to the north-east, just off Gupta's map.

The sample received consisted of large and small fragments of monazite crystals, some of which must originally have been several inches long. Most of the material was clean, apart from occasional adhering flakes of muscovite, but the fractured surfaces show evidence of patchy internal decomposition. The fresh-looking portions are

yellowish-brown and resinous, but these are veined and surrounded by duller material. Many smaller veinlets and fractures could be seen in thin section. After crushing, the most resinous portions, free from visible veins, were picked out and prepared for the analysis made by Mr. Smales (see p. 300). As before, the lead isolated during the analysis was converted into pure lead iodide and sent to Professor Nier. The results of the isotopic analysis by Leland and Nier are recorded in Table II.

TABLE II

MONAZITE, SONIANA, MEWAR STATE, INDIA

Chemical Analysis (A. A. Smales):

Pb	U	Th	$\frac{Pb}{U + Th}$	$\frac{U}{U + Th}$	*Apparent Age (m.y.)*
·525	·68	16·45	·0306	·04	620

Isotopic Analysis of Lead (W. T. Leland and A. O. Nier):

Isotopic Proportions	Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
In Total Lead	·008	13·58	1·03	100·00
In Original Lead *	·008	·14	·12	·29
	—	13·44	0·91	99·71
Per cent of Radiogenic Lead in Monazite.		·062 RaG	·0042 AcD	·457 ThD
	$\frac{AcD}{RaG}$	$\frac{RaG}{U}$	$\frac{AcD}{U}$	$\frac{ThD}{Th}$
Ratios	·0677	·0912	·0062	·0278
Apparent Ages (m.y.)	865	660	700	613

* The approximate isotopic proportions of ordinary lead formed about 700 m.y. ago is taken as

Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
1	17·07	15·46	36·85

Chemically, this monazite is of interest in containing more Th and U than any other monazite hitherto analysed for age purposes (for list, see Holmes, 1948*b*, p. 120). On the other hand, as shown below, it contains less original lead than any other fully investigated monazite. The crude age read from Wickman's family of graphs is 620 m.y., which is considerably lower than the uraninite age, suggesting that the mineral has suffered loss of lead. The isotopic analysis confirms this inference.

The isotopic constitution of the lead in this case is stated in proportions relative to Pb^{208} taken as 100. The proportion of Pb^{204} is ·008, corresponding to the presence of ·002 per cent of original lead in the newly crystallized monazite. The isotopic constitutions of lead from three other monazites have been determined by Nier, Thompson, and Murphey (1941, p. 113), and from the proportion of Pb^{204} in each an estimate of the original lead can be similarly made. The results,

together with the present one, are given in the last column of Table III. These very minute amounts confirm the geochemical expectation that lead, apart from radiogenic lead, would be only a trace element in monazite.

TABLE III

PERCENTAGES OF ORIGINAL LEAD IN MONAZITES

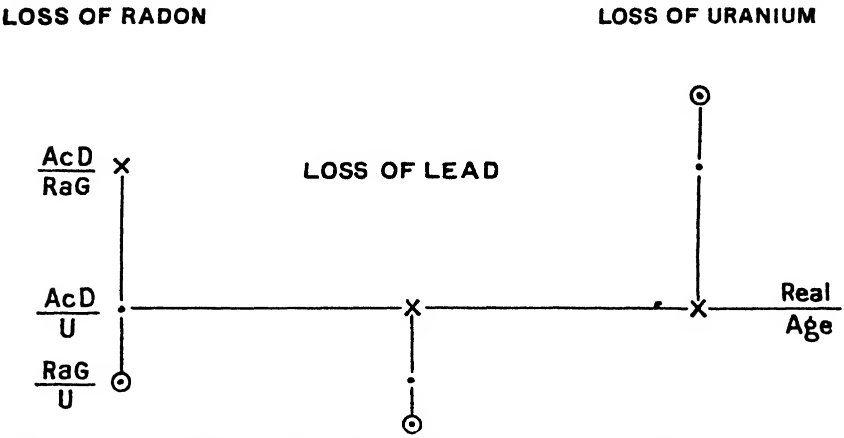
Locality of Monazite	Age in m.y.	Isotopic Proportions of Lead ($Pb^{208} = 100$)		Percentage of Lead in Monazite	
		Total	Pb^{204}	Total	Original
Huron Claim, Manitoba .	1985	113·721	·011	1·524	·013*
Mt. Isa, Queensland .	1200	106·891	·041	·285	·008
Las Vegas, New Mexico .	1330	111·378	·028	·372	·007
Soniana, India . .	735	114·618	·008	·525	·002

* As a result of misplacing a decimal point this figure is wrongly given as ·001 in Holmes, 1948*b*, p. 119.

In Table II the isotopic proportions of the original lead are subtracted from those of the total lead, the balances being the proportions of the radioactive isotopes RaG, AcD, and ThD. The respective " ages " are then calculated as indicated on p. 293. It will be noticed that the " ages " vary through a considerable range, a fact which testifies to the altered character of the mineral. The " ages " calculated from RaG/U, AcD/U, and AcD/RaG will of necessity depart considerably from the real age, according as the mineral has suffered loss of radon by gaseous diffusion, or loss or gain of uranium and/or lead (e.g. by weathering). For example, if part of the radon has been lost during the lifetime of the mineral, RaG will be deficient (Wickman, 1942). In this case the " age " from RaG/U will be too low, that from AcD/RaG will be too high, and, provided there has been no other alteration, the correct age will be given by AcD/U. The resulting sequence of " ages " is illustrated graphically in Text-fig. 2, which also shows the pattern of the results obtained when there has been loss of Pb (or gain of U) or loss of U (or gain of Pb). In these cases the age from AcD/RaG will be the correct one, if the alteration has been recent, since the ratio is independent of U and is unaffected by chemical changes involving Pb as a whole. And even if the alteration took place long ago the age is still very nearly correct (see Holmes, 1948*b*, Fig. 2, p. 121).

Applying these principles to the Soniana monazite it will be seen that the sequence of the " ages " corresponds to either loss of radon or loss of lead or both. The age from ThD/Th is too low and that points to loss of ThD. Now, since it is difficult to see how ThD could be lost without a corresponding loss of all the associated isotopes of

lead, it can be concluded that the mineral has suffered loss of lead. If this were all, the most probable age would be 865 m.y. However, it is easy to show that such alteration fails to account for the actual



TEXT-FIG. 2.—Diagram illustrating the effects of various types of alteration on the apparent ages of radioactive minerals calculated from AcD/RaG (crosses), AcD/U (dots), and RaG/U (dots and circles). The horizontal line represents the true age of the mineral, points above and below being respectively too high and too low.

discrepancies. Suppose we imagine lead restored to the mineral in sufficient amount to raise the thorium " age " from 613 to 735 m.y. The " ages " then become :

$\frac{AcD}{RaG}$	$\frac{AcD}{U}$	$\frac{RaG}{U}$	$\frac{ThD}{Th}$
865	803	784	735

Comparison of this sequence with Text-fig. 2 shows that the pattern is still that corresponding to loss of radon. Moreover, the fractured condition of the mineral makes it inevitable that loss of radon must have occurred. From the " ages " given in Table II it is clear that, if the discrepancies were due to loss of radon alone, the most probable age would be 700 m.y. Obviously, like other monazites (cf. Holmes, 1948*a*, p. 192), this one has been subjected to alterations too complex for satisfactory interpretation. The results can be brought into agreement only by assuming that radon, Pb and U have all been lost in appropriate amounts. All that can be deduced with certainty is that the age lies between the limits of 700 and 865 m.y. This conclusion, though unsatisfactory in itself, is at least consistent with the reliable age estimate of 735 m.y. determined from the uraninite.

V. The Pre-Cambrian Sequence in India

The only other orogenic belt in India that has been approximately dated by analysis of radioactive minerals is the Satpura Belt (Text-fig. 1). The general sequence is

Pegmatites, etc.
Granites and migmatites
Iron Ore Series

Sausar and Gangpur Series

The general strike is E.N.E.–W.S.W., and is commonly known as the "Satpura Strike" (Krishnan, 1943). The name of the belt is taken from the Satpura Range, which, though largely capped by Deccan Traps, has an exposed core of ancient metamorphic rocks, migmatites, granites, and pegmatites, with the foliation roughly following the general direction of the Range. Fermor regards these rocks as a geological extension of the "Archaean" rocks of Chota Nagpur, and Crookshank (1936, pp. 196 and 208) provisionally classifies them with the Sausar Series, apart from an isolated group of banded haematite-quartz rocks, which may possibly be the equivalent of part of the Iron Ore Series.

A summary of the geology of Chota Nagpur and of the minerals found in the pegmatites associated with the Chota Nagpur granite in Bihar is given by Dunn (1942). The pegmatites of the Gaya and adjoining districts constitute the world's leading source of muscovite. Radioactive minerals have been found in certain localities, notably around Singar, 35 miles E.S.E. of Gaya, and at Ranchi, 100 miles S.S.E. of Gaya, and some of these have been analysed (Table IV).

TABLE IV

THE "AGES" OF URANINITE AND MONAZITE FROM MICA-PEGMATITES NEAR SINGAR, GAYA DISTRICT, BIHAR

	Pb	U	Th	$\frac{Pb}{U+Th}$	$\frac{U}{U+Th}$	*Apparent Age in m.y.*
A.	8·66	67·46	(7·0)	(·116)	(·90)	(830)
B.	8·92	64·30	8·12	·123	·89	885
C.	·49	·23	10·55	·045	·02	960

A. Uraninite. *Analyst*: W. R. Criper, in T. H. Holland, *Mem. Geol. Surv. India*, 34, 1902, p. 131. Criper did not determine ThO_2, but from his analysis it is clear that this could not have exceeded 8 per cent. Th is therefore taken as 7 per cent. Without Th the "age" is 850 m.y.

B. Uraninite. *Analyst*: A. Holmes, 1918, p. 86. Only Pb and U were determined originally, as it was not then realized that the end product of thorium was also an isotope of lead. To complete the analysis Th was determined on a sample of the same powder in 1932.

C. Monazite. *Analyst*: T. C. Sarker (1941).

The "age" calculated from my analysis of uraninite is almost certainly too low, as the mineral, though free from visible alteration products, was riddled with cracks. Loss of radon would seem to have been inevitable. This uncertainty will shortly be cleared up, as Professor Nier has undertaken the isotopic analysis of lead separated from the

analysed powder. Criper's analysis gives an " age " of the same order, but his material was also of inferior quality and again the loss of radon which is suspected would lead to a low result. Sarkar's monazite " age " is likely to be of the right order, but it is impossible to say whether it is too high or too low (cf. Holmes, 1948*b*, p. 123, for evidence that monazite may give results either way). Meanwhile it may be concluded that the age of the minerals is not far from 900 m.y.[1]

The above evidence is adequate to show that the Satpura Belt represents the geological cycle immediately preceding the Delhi Cycle. Moreover, if the correlation of the ancient rocks of the Satpura Range with the Sausar Series is correct—and the apparent continuity of trend (see Text-fig. 1) strongly supports the views of Fermor and Crookshank—then it follows that the Aravalli System and the orogenic belt to which it belongs are older still. The broad sequence in the Pre-Cambrian areas of India under consideration thus appears to be as follows :—

Vindhyan

735 m.y.
DELHI CYCLE (= Cuddapah ?)

ca. 900 m.y.
SATPURA CYCLE

ARAVALLI CYCLE (= Dharwars ?)

GNEISSIC COMPLEX (= Bundelkhand in part ?)

The Dharwars referred to in the above chronological classification are the N.W.–S.E.-trending rocks of Southern India (e.g. Mysore ; see Rama Rao, 1936). There can be no doubt that these rocks represent a very ancient orogenic belt and possibly more than one. The relative age of the belt can be arrived at by another route. The Dharwar belt is sharply cut across by the Eastern Ghats belt (Krishnan, 1943*a*) which must therefore represent a younger cycle. The Eastern Ghats belt in turn appears to be cut across by the Satpura belt. Krishnan, for example (1943*a*, p. 141), writes : " My observations in parts of Orissa seem to show that the Satpura strike is later than and superimposed on an earlier one, apparently that of the Eastern Ghats." Unfortunately, the evidence from radioactive minerals in the case of the Eastern Ghats belt is at present highly discordant. Minerals suitable for dating purposes occur in the mica-pegmatites of the Nellore

[1] Since the writing of this paper, Dr. Leland and Professor Nier have completed the isotopic analysis of lead from sample B. The results, which will be published in *The American Mineralogist*, show that the age is 955 ± 40 million years.

district, amongst them samarskite. Two analyses of samarskite have been made (Table V). Attention is directed to this extraordinary discrepancy in the hope that the analysts concerned will meet the challenge by repeating and continuing their work.

TABLE V

SAMARSKITES FROM THE MICA-PEGMATITES OF THE NELLORE DISTRICT

	Pb	U	Th	$\frac{Pb}{U+Th}$	$\frac{U}{U+Th}$	*Apparent Age.*
A.	·54	4·07	1·17	·103	·78	830
B.	2·09	7·41	1·74	·228	·81	1550

A. *Analysts* : Sarkar and Sen Sarma (1946).
B. *Analysts* : Karunakaran and Neelakantam (1948).

At the moment, however, it can be concluded either that the Satpura and Eastern Ghats belts are of about the same age or that the Eastern Ghats belt is older than the Satpura belt. The tectonic evidence strongly favours the second view. In either case the Dharwars are older than both. Rocks of the Eastern Ghats and Satpura belts should therefore no longer be referred to as " Dharwars " as they commonly have been in the past (Krishnan, 1935 ; Fermor, 1936, p. 214). To do so would be to perpetuate a mistake that is analogous to the misuse of the term " Laurentian " in North America. The original Laurentian rocks of the Grenville Province have a closing age of just over 1,000 m.y. (Holmes, 1948*a*, pp. 180–4). The post-Keewatin pegmatites of the Rainy Lake area have an age of nearly 2,000 m.y. (Holmes, 1948*a*, pp. 189–193 ; Ahrens, 1949). Yet the post-Keewatin granites and migmatites have also been called " Laurentian ", implying an entirely unjustified correlation with rocks 800 miles away and completely unconnected. Similar mistakes have been made in all the better-known Pre-Cambrian shields and only now, with the progress of mapping and the aid of radioactive minerals, is it becoming possible to disentangle the long succession of orogenic belts which make up the so-called " Archaean ", once thought to represent an era of world-wide orogenesis.

VI. METHODS OF CHEMICAL ANALYSIS (by A. A. Smales)

Uraninite.

The *lead* was determined gravimetrically as sulphate on 5 gm. sample, after filtering off silica rendered insoluble by evaporation of the nitric acid solution. Alcohol was not added to complete the precipitation of the lead sulphate since the filtrate was required for the determination of thorium and uranium. Instead the amount of lead remaining in solution was determined by the following procedure :—10 ml. 0·005 N $CdCl_2$ solution were added to an aliquot of the filtrate equivalent to 1 gm. sample, the acidity adjusted to approximately N/100,

and the lead and cadmium precipitated as sulphides by a stream of H_2S. The combined sulphides were then dissolved in hydrochloric acid, H_2S was boiled off and lead determined polarographically after diluting so that the final HCl concentration was 1N (see Smales, 1948). The cadmium added may also be determined polarographically simultaneously, affording evidence that the H_2S precipitation is complete. The amount of lead recovered in this way was 0·40 mg. (=0·04 per cent) in each of two duplicates; the main gravimetric lead figures being 7·92 and 7·90 per cent Pb, giving a total lead of 7·96 and 7·94 per cent; average 7·95 *per cent Pb.*

Thorium was determined on 2 gm. aliquots of the lead sulphate filtrate by precipitation first as oxalate and then as peroxynitrate. Since the amount of ThO_2 so obtained was lower than was expected, a further determination was carried out on 10 gm. sample. The figures obtained were 1·3, 1·3, and 1·5 per cent Th; average 1·4 *per cent Th.*

Uranium was determined both gravimetrically and volumetrically on 0·5 gm. aliquots of the lead sulphate filtrate; gravimetrically as U_3O_8 after allowing for rare earth plus thorium oxides in the precipitate obtained with ammonium hydroxide in the absence of CO_2; volumetrically by titration with permanganate after passing through a Jones reductor, trivalent uranium being oxidized by a gentle stream of air before addition of ferric alum solution. Results obtained were 72·9 and 72·7 per cent and 73·0 and 73·1 per cent U respectively; average 72·9 *per cent U.*

Monazite.

Lead was determined both by the gravimetric method of Schoeller and Powell (1940) on 10 gm. sample, care being taken to keep the acidity for the lead sulphide precipitation as low as possible; and by the polarographic method (on 1 gm. sample) used in a previous analysis of monazite (Smales, 1948) where the amount of sample was limited. Results obtained were 0·535, 0·526 per cent and 0·52, 0·52 per cent respectively; average 0·525 *per cent Pb.*

Thorium was determined as usual on a 1 gm. sample via oxalate and peroxynitrate, the latter precipitation being carried out three times to ensure separation from cerium. Results obtained were 16·4, 16·5 per cent; average 16·45 *per cent Th.*

Uranium was determined polarographically on a 1 gm. sample by the method used previously (Smales, 1948), directly after removal of lead as sulphate, since it was shown that separation of thorium and rare earths, and of any titanium present was unnecessary, providing the latter was present in the quadrivalent state. Results obtained were 0·68 and 0·68 per cent; average 0·68 *per cent U.*

VII. Lead Isotope Analyses (by W. T. Leland and A. O. Nier)

As in earlier work (Nier, 1939 ; Nier, Thompson, and Murphey, 1941), the isotopic analyses were made with a mass spectrometer. Basically, the present instrument is similar to those used earlier. PbI_2 vapour is ionized by electron impact, the ion beam after suitable acceleration is sent through a magnetic field to accomplish a mass separation and the ion currents are measured electrically. There are, however, a number of major differences in the present apparatus : (1) Instead of filling an entire section of the spectrometer tube with lead iodide vapour a small furnace installed in the ion source acts as a source of vapour (Nier, 1938). (2) The mass spectrometer employs a 60° magnetic field and is very similar to another we already described (Nier, 1947). The stronger magnet described at the end of that article is employed. (3) Readings are taken with a recording potentiometer rather than manually. Readings were taken in both the Pb^+ and PbI^+ positions of the spectrum. Because of the improved efficiency of the present apparatus, analyses have been made on as little as 3 mg. of PbI_2. A more complete description of the new apparatus and its applications will appear elsewhere.

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Hilt's Law and the Volatile Contents of Coal Seams

By O. T. Jones

ABSTRACT

Dr. Trotter's recent theory of devolatilization of coal seams is criticized on structural grounds and the " square law " suggested is shown to be no improvement on many other expressions of varied types. The data are best represented both for South Wales and the Kent Coalfield by Hilt's law. The influence of depth of burial on coal vegetation is discussed ; loss of volatile matter is probably promoted by temperatures, but is almost certainly retarded by high pressures. The Hilt rate is controlled by the chemical-physical factors and may be influenced also by varying rates of sedimentation during the accumulation of the Coal Measures.

THE change in the volatile content of coal seams with depth in a vertical sequence which has been observed in coalfields has been variously attributed to (1) the presence of a body of magma below the coalfield, (2) the effect of tectonic forces, and (3) the depth to which the seams were formerly buried beneath the surface. The question has attracted fresh notice recently as the result of a paper by Dr. F. M. Trotter, 1949, on the Coal Seams in South Wales.

That author explains the loss of volatiles with depth as due to " pressure by tectonic forces ", and maintains that the view which attributes the process to magmatic heat has few adherents to-day except to explain local effects due to the intrusion of dykes or sills into or in close proximity to a coal seam.

Dr. Trotter's theory is based upon the supposed existence of a plane of Main Thrust which is identified at the surface with the well-known Careg Cennen disturbance but which, unlike that disturbance everywhere else along its outcrop, is supposed to be a great thrust from the south which passes with a very low inclination under the coalfield. The formula in which the theory is embodied involves the inclination of this plane at any point ; it can be written :—

$$\sqrt{V_2} = \sqrt{V_1} - \frac{\cos\theta}{K} Y$$

where V_2 and V_1 are the volatiles of two seams in a vertical sequence at a depth Y apart ; K is a constant and θ is the inclination of the plane. Since there are fifty-seven seams represented in various sequences in the coalfield (see pp. 409–412) there are many pairs of volatiles which when plotted against the depth between them would give $-\frac{\cos\theta}{K}$. The general result is that there is no evidence in the figures that θ departs significantly from zero. Dr. Trotter believes that he has obtained the dip from the isovols, and that for a large portion of the

western coalfield it is not more than 5° ; cos 5° differs from 1 by only $3\frac{1}{2}$ parts in 1,000. Thus the isovols which are plotted on a horizontal plane are viewed as if projected on a plane dipping at about 5°. The Main Thrust is supposed to control the volatile content of seams, some of them at a distance of two miles. One must presume that the author believes that the shearing movement on its surface caused a great rise of temperature along the plane ; it would, therefore, be analogous to inserting a hot plate beneath the coalfield—whether the plate be horizontal or sloping at 5° is immaterial. The square law is the last effect that one would expect to follow from the theory of heat conduction ; it seemed, therefore, possible that this law or $V \propto y^2$ might be an illusion and so, indeed, it proved to be. I applied various other types of curves to the available data, viz. the following :—

$V^2 \propto y$ (an inverse parabola), $\frac{1}{V} \propto y$ (a rectangular hyperbola), $V \propto y$ (a straight line, or Hilt's law), $\log V \propto y$ (exponential), and $\log R \propto y$, where R is the percentage ratio of volatile to fixed carbon, or $R = \frac{100V}{100-V}$; in each case V is the volatile content and y the depth below a given datum. Wellman, 1948, claimed that this last expression gave satisfactory results for the Kent Coalfield. In determining the constant K, Dr. Trotter selected three out of the nine sequences which were available ; he then assumed that the volatile contents of the seams at the top and the bottom of each of the three sequences accurately conformed to the square law (omitting any reference to cos θ) and disregarding all the other seams in each sequence, found his constant from these two seams alone combined with the vertical distance between them. The correct method is to determine the constant for each sequence by a least squares solution, taking account of all the data for each sequence. Even so, however, there are such wide differences between the values of the constant for the various sequences that obviously no single value can be applied to the coalfield as a whole (see below). The fact must therefore be faced that *this mathematical law which involves a fixed constant cannot possibly be applied to the South Wales Coalfield*, and for this reason Dr. Trotter's theory must be rejected, or at best regarded as a poor approximation.

The values obtained by least squares for each sequence from east to west are as follows :—Blaenavon (2188), New Bridge* (2066), Bargoed (1742), Blaengarw* (1774), Penrhiwceiber (1582), Treherbert (1445), Resolven* (2056), Dulais Valley (2593), and Gwendraeth Valley (4630), those selected by Dr. Trotter being indicated by a star. The value corresponding to these which was adopted by Dr. Trotter is 2050 or 1450 $\times \sqrt{2}$. The mean of the figures for the three sequences

selected by Dr. Trotter is 1965, but this is the geometric mean, the arithmetic or true mean being 1957 as compared with 2050 adopted. The average for all the above sequences, which are of variable depth ranges, was obtained by giving weights to each value proportional to the depth range of that sequence; the true mean of all the above is thus 1970 $\pm$ 630, but if we exclude the value for the Gwendraeth Valley the true mean is 1910 $\pm$ 230.

The result of trying to force a particular value (2050) of the constant on to every sequence is seen in the poor correspondences between calculated and observed values shown on pp. 409–412. The sum of the squares of residuals in these correspondences is very large in comparison with those obtained from any one of the various expressions referred to above, even the worst of them (see table).

COMPARISON OF VARIOUS FORMULAE

	S Vo	S Vc	S·Δ	S Δ²
Dr. Trotter's calculations (pp. 409–412) .	963·8	952·7	38·8	61·19
The remainder are all least squares solutions.				
Dr. Trotter's Square law			33·2	36·86
Hilt's law	-		32·6	34·58
Inverse parabolic law	--		36·1	37·40
Rectangular hyperbolic law			37·4	58·21
Exponential law	--		33·7	40·19
Wellman's law	-		32·0	36·96

In this table S stands for the sum of and Δ for the residual or difference between observed and calculated volatile percentages.

It will be seen that judged by the sums of the residuals and the sums of their squares, the results derived from the application of the above expressions to the South Wales sequences fall into the following order of merit: Hilt's law, Wellman's exponential ratio law, Trotter's square law correctly applied, the inverse parabolic law (which runs it close), the exponential law, the rectangular hyperbola, followed last of all by Dr. Trotter's own calculations.

The sums of the calculated volatiles on a least squares solution must agree closely with the sums of the observed volatiles in any given sequence and are not therefore given in the Table but according to Dr. Trotter's own calculations they do not agree.

It may appear strange that given data representing the relations between volatiles and depths can conform in varying degrees of approximation to such very diverse laws as $V \propto y^2$ and $V^2 \propto y$. The reason is that the volatiles/depth curve is so nearly straight for ranges

of depth of the order of 2,000 feet that any curve, if its origin is at some distance away, becomes virtually a straight line within that range. Added to this there is a considerable " scatter " of the residuals which seems to be inherent in coal seams so far as is at present known and is several times the probable error of the analytical determinations.

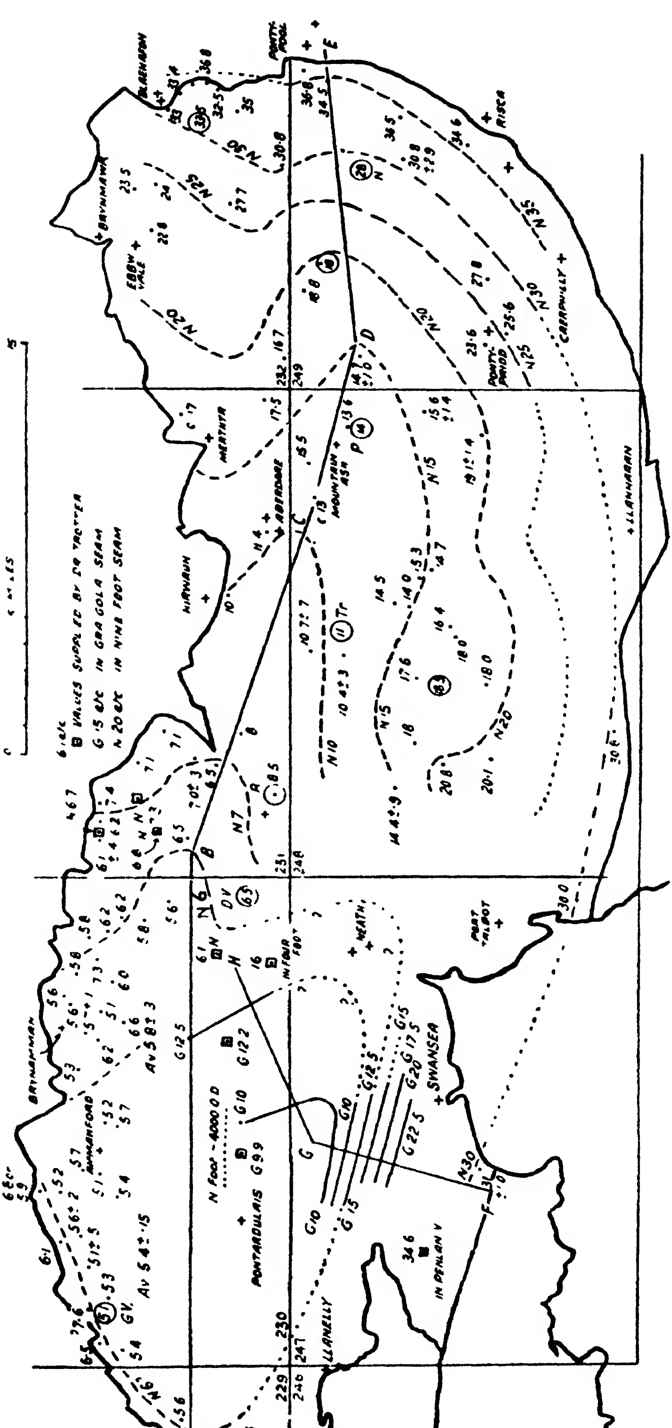
The result of the somewhat laborious calculations embodied in the above Table is to show that Hilt's law is sufficient for all practical purposes and no advantage is gained by using any other law.

Besides examining the validity of Hilt's law a further object of this paper is to see how far the remaining theory that devolatilization is a consequence of the former burial of coal seams to a depth of many thousands of feet below the surface can account for the loss of volatiles in coal seams. Three sets of data are examined which are derived from (*a*) the South Wales Coalfield, (*b*) the Kent Coalfield, and (*c*) the Pie Rough borehole, North Staffordshire.

(*a*) The South Wales Coalfield

The Geological Survey published a large number of chemical analyses (Pollard and Strahan, 1908) of various seams from this coalfield. Many of these analyses were made in the Geological Survey laboratory, and both proximate and ultimate analyses are given. In view of the large variations in volatile percentages within the coalfield, minor errors which may occur in comparison with modern analyses are relatively of little importance. From the recorded proximate analyses I constructed for the eastern and north-western parts of the coalfield a map showing the distribution of the volatile contents of the Nine-Foot seam which has been approximately correlated from one end of the coalfield to the other ; again, in view of the scale of the phenomenon, minor errors of correlation have little effect upon the picture. The distribution of volatiles is indicated by lines of equal volatile percentages or isovols, but the actual percentages are also recorded on the map. Where values were obtained by transferring from other seams just above or below, their means and probable errors are given (Text-fig. 1).

Since 1930 the Fuel Research Coal Survey which, until it was transferred to the National Coal Board in 1947, was under the Department of Scientific and Industrial Research, have carried out a large number of new analyses which have not yet been published. On the basis of the proximate analyses which were made the officers of the Coal Survey, 1944, published (*a*) an isovol map, and (*b*) an explanatory pamphlet. This map (reproduced in Trotter, fig. 8) was also based in the main upon the Nine-Foot seam and what were believed to be its correlatives in various parts of the field. The isovol map based on the



TEXT-FIG. 1.—Isovol map of the S. Wales coalfield based on the Strahan-Pollard coal analyses. The south-west portion based on the Coal Survey isovol map (1944).

Strahan-Pollard analyses and that constructed from the more recent analyses differ only in minor details and it would be difficult in most areas to prove that there is any difference between them. For the region north-west of Swansea, however, the Strahan-Pollard analyses are not sufficient to do more than indicate the general trends of the isovols in the seams which are there worked. These seams lie in or just above the base of the Pennant Sandstones and thus some thousands of feet above the horizon of the Nine-Foot seam. The Coal Survey map gives a much better representation of the isovols of the principal seams and I have adopted them, but referred them all to one seam, the Graigola (G). The significant features of these maps are (1) the parallelism between the isovols N_{30} or N_{35} and the present margin of the field from Blaenavon on the east to Gower in the west; (2) by contrast the trend of the isovols across the northern margin indicating that a large area of the former Coalfield has been removed by erosion; (3) the two isovol minima, one running in the length of the field, and the other ranging N.W.–S.E. north-west of Swansea. These reflect the former geological history of the field.

The Ministry of Fuel and Power, 1946, published a list of nine vertical sequences of coal seams with their volatile percentages and the depth of each, by reference to some datum. These were also got together by the South Wales Coal Survey. These sequences are given in Dr. Trotter's paper (pp. 409–412) and, together with the isovol maps, must form the basis of any investigation made at the present time into the relation between volatile percentages and existing or former depth of burial in the South Wales Coalfield.

Hilt's Law

It has long been maintained that there is a decrease in the volatile content or an increase in the carbon content of coal seams with increasing depth at any part of a coalfield; this is usually stated as Hilt's law. The validity of this law has not been adequately tested hitherto, but the nine vertical sequences mentioned above afford a good opportunity for doing so. A linear relation between volatile percentage and depth in a given sequence is assumed, so that if Vo is the probable percentage of volatiles in the top seam of a sequence and V that in a lower seam at a depth y below the horizon of Vo,

$$V = Vo - hy$$

where h is a constant which is called herein the Hilt rate. It is convenient to represent this rate as the change per cent of volatiles per 1,000 feet of depth. The constants Vo and h have been determined by the method of least squares. The results are contained in the following Table.

Sequence and Page	Range of Depth in Feet	h	Sum of Residuals +	Sum of Residuals −	Sum of Squares of Residuals
Blaenavon and Varteg (p. 409)	785	5·31	2·1	2·1	4·90
*New Bridge and Crumlin (p. 410) . . .	1,905	5·32	3·6	3·6	11·58
Bargoed (p. 410) . .	2,365	5·53	2·8	2·7	5·35
*Blaengarw (p. 410) . .	2,055	5·20	3·3	3·3	7·86
Penrhiwceiber (p. 411) .	2,378	5·50	1·3	1·2	2·35
Treherbert (p. 411) . .	1,648	5·26	1·3	1·4	1·35
*Resolven (p. 412) . .	2,457	3·31	·8	·7	·67
Dulais (p. 412)[1] . .	2,082	2·18	·6	·6	·24
Gwendraeth Valley (p. 412)	805	·97	·5	·7	·28
			16·3	16·3	34·58

Those marked with a * were used by Dr. Trotter to determine the constants in his formula.

The first six sequences are in the eastern half of the coalfield and their mean, weighted according to the range of depth over which each holds, is $5{\cdot}37 \pm {\cdot}11$ which is an average rate of change of 1 per cent in a depth of 186 feet. The uniformity of the rate is noteworthy, especially when it is compared with the marked and progressive decrease which sets in farther west between Treherbert and Resolven. These three western sequences correspond to a rate of change of 1 per cent in 302 feet, 459 feet, and 1,031 feet respectively. These figures illustrate very clearly the difficulties that anyone must encounter in attempting to apply Hilt's or any other law with a uniform constant to the coalfield as a whole. There is no doubt, however, that, within the limits of variation which at present appears to be inherent in different coal seams, Hilt's law holds for this coalfield not only in a qualitative sense but quantitatively. Before dealing with the significance of these varying rates in the South Wales Coalfield, it is interesting to see how they compare with those in the Kent Coalfield.

(*b*) The Kent Coalfield

The stratigraphy of this coalfield was described by H. G. Dines, 1933. The coal measures are about 2,800 feet thick and are overlain unconformably by Mesozoic rocks, the base of which lies roughly between 800 feet and 1,400 feet below Ordnance Datum (see Dines, fig. 1). Some mine shafts and numerous boreholes enable the depth to the base of the Coal Measures to be ascertained as illustrated by a contoured map (Dines, fig. 2). In the main the Coal Measures

[1] The lowest seam at 2082 is omitted by Dr. Trotter.

rest with a non-sequence on Carboniferous Limestone but towards the north-west they transgress on to older rocks. The deepest part of the basin is at Waldershare (3,850 feet below O.D.), and its axis there ranges east-south-east towards Maydensole; westward the course of the axis becomes indefinite. Folding of the basin " in the main post-dated the deposition of the coal-bearing strata, although there is evidence that it was in progress during their deposition ".

The lowest 700 feet consists of shales with coal seams but towards the north-western part of the field sandstones appear among these shales. The upper part consists mainly of sandstones with coal seams; near their base the Millyard seam is widely developed and at their top the Beresford seam is found over a small area beneath the Mesozoic cover. " There is a slight diminution in the thickness of the strata between the Beresford and the Millyard seams outwards from the centre of the basin suggesting that folding was in progress during deposition."

Apart from some disturbances in the seams which in many respects resemble washouts, the rocks are little disturbed and with minor exceptions the beds dip gently at angles not exceeding 4°. There do not appear to be any large faults though some faults with small downthrows have been found in all the workings. The tectonic effects in this coalfield are therefore trivial in comparison with those in the South Wales Coalfield.

The volatile contents of the seams vary between 35 per cent and 10·5 per cent, and cover, therefore, exactly the same range as the six eastern sequences of South Wales. The lowest seams just fail to reach the anthracite rank of 9·5 per cent.

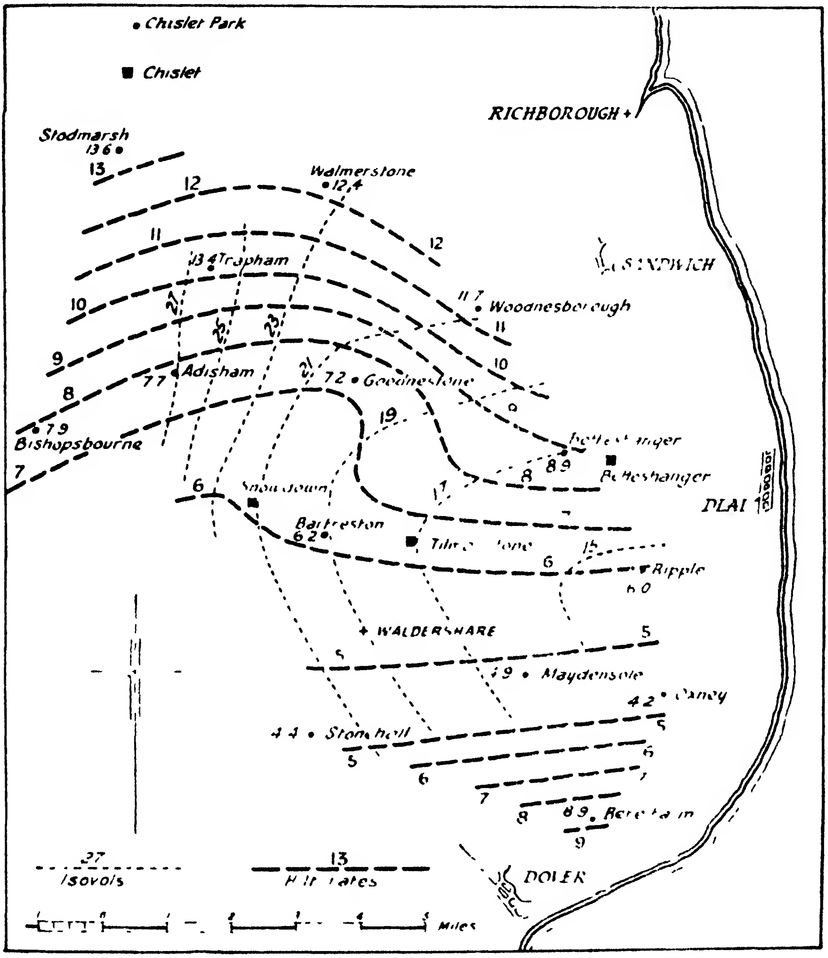
As the isovols in the Beresford and Millyard seams show (Dines, figs. 4 and 5), the volatile percentages decrease from west to east and thus in the opposite direction from South Wales. The lowest volatiles do not coincide with the deepest part of the basin, and their horizontal variation cannot be accounted for by the present conditions in the field. Dines remarks, " it is possible that the present distribution of the volatiles was determined by a cover of strata overlying the Coal Measures which was removed before the present cover was laid down."

The volatiles decrease generally in a vertical direction but there are some exceptions where the depth interval is not large. On the whole, however, it is obvious that in a qualitative sense Hilt's law holds.

There are fourteen vertical sequences based on boreholes and one based on colliery workings, for which volatile percentages of the seams are known; these furnish a good opportunity of testing Hilt's law for this Coalfield. The constants were determined for all sequences

by least squares. As for South Wales many other expressions were also tried for comparison but none of them show any advantage over Hilt's law.

The Hilt rates for each sequence are shown in Text-fig. 2. There is a



TEXT-FIG. 2.—Distribution of Hilt rates and isovols of Millyard Seam, Kent Coalfield.

remarkable decrease in the rates from north to south, the rate at Oxney being less than one-third of the rate at Stodmarsh and it is evident from their distribution that the variation of Hilt rates is systematic. The figures for Trapham are somewhat erratic and may include some errors. This place does not fall into line with surrounding places. There is, unfortunately, only one sequence, Bere Farm, in the south ; the rate there appears to indicate an increase to the south even more rapid than anywhere farther north. These lines of equal

rates appear to define sharply an axis ranging nearly through Oxney and Stonehall along which the Hilt rate hardly exceeds 4 per cent per 1,000 feet. On the same map some of the isovols of the Millyard seam, taken from Dines' map (Text-fig. 5) are shown.

It is obvious that there is no direct relation between the trends of the Hilt rates and those of the isovols ; in fact, the two trends are nearly at right angles. This, together with the fact that the minimum axis of the volatiles does not coincide with the deepest part of the basin, have proved serious stumbling blocks in attempting to account for the variation of Hilt rates in this coalfield, and no satisfactory explanation has been offered.

(To be concluded.)

New Species of Calymenidae from Scotland and Ireland

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(PLATE XVIII)

ABSTRACT

Four new species of Calymenidae distinctive of horizons of stratigraphical interest are described. Observations of two pairs of anterior pits in the axial furrows of *Platycalymene éire* sp. nov. and *P. duplicata* (Murchison), not corresponding with the first lateral furrows of the glabella, indicate a trisegmental origin of the frontal lobe. A possible correspondence of the trilobite hypostome with chelicerae of Arachnids is propounded.

Family CALYMENIDAE Milne Edwards, 1840

Genus PLATYCALYMENE Shirley, 1936

Platycalymene éire sp. nov.

Pl. XVIII, figs. 1–2

Diagnosis.—Glabella low, narrowing in front, parabolic. Median part of occipital ring arched up and longer than lateral parts which are narrow and point slightly forwards. Third (basal) glabellar lobes pointed in front but not projecting beyond outline of glabella. Third glabellar furrows oblique, deep, continued backwards in a groove which turns nearly parallel to axis of glabella, only becoming shallow just before it meets the occipital furrow. Anterior outline of frontal lobe well rounded ; the lobe rises steeply but not high above preglabellar field ; no overhang ; greatest width immediately behind small anterior pits. Preglabellar field only gently uptilted ; anterior half with moderate roll-like thickening.

Anterior margin of cranidium convex forwards and gently convex over axis. Cheeks extend further forward than glabella, descend steeply to axial furrows or even overhang a little. Axial furrows wider opposite frontal lobe and second glabellar lobes, but narrowing somewhat where raised eyelines run forward and inward to reach floor of furrows opposite rear of frontal lobe. Slight convexity in a lateral direction of floor of axial furrow between small pit at end of eyeline and faint anterior pit opposite narrowing part of frontal lobe. Palpebral lobes roughly opposite rear half of first glabellar lobes. In this position fixed cheek is about half width of glabella. Cheek rises steeply from posterior marginal furrow which meets axial furrow at an angle of about 75°. Posterior border of cheek is narrow and runs obliquely forward.

Surface ornament, thorax, and pygidium unknown.

Dimensions.—Length of cranidium, 10·7 mm. ; length of glabella, 7·5 mm. ; width of glabella across basal lobes, 7·0 mm.

Holotype.—Lamont Collection No. 36.

Horizon.—Lower, less muddy facies of Stage 3 of the Tramore Limestone ; not far under beds with *Nemagraptus gracilis.*

Locality.—Roadside, Newtown Glen, 1½ miles south-south-west of Tramore, County Waterford.

Remarks.—*Platycalymene éire* occurs on the same small slab with *Trinucleus hibernicus* Reed, *Remopleurides salteri* Reed, and fragments belonging to *Tramoria punctata* Reed.

The most instructive comparison seems to be with *Platycalymene duplicata* (Murchison) *forma mas* Salter, which is illustrated in Pl. XVIII fig. 4. In it the proportions of glabellar length to breadth across basal lobes correspond with those of *P. éire*, but in the latter the anterior part of the glabella is much narrower. In both forms of *P. duplicata* the anterior roll is more pronounced, the cheeks much wider, and the extended eyeline ends in the axial furrow close to a pit—possibly antennary—just behind the anterior pit (Pl. XVIII, figs. 3–4).

These pairs of anterior pits, of which the front pair may be somewhat elongate laterally, point to a trisegmental origin of the frontal lobe. The front pair may indicate points of attachment of appendages which have fused to give the hypostome. This hypothesis is supported by the existence of clawlike projections on the posterior margin of young Calymenid hypostomes. There may even be homology with the chelicerae of Arachnids, e.g. *Hughmilleria* (Clarke and Ruedemann, 1912, pl. 59, fig. 2). The rostrum in Calymenidae may correspond with the epistome in *Hughmilleria* (compare Stubblefield, 1936, fig. 2*c*, or Henriksen, 1926, fig. 8, with Størmer, 1944, fig. 9, no. 6).

The lateral parts of the occipital ring in *Platycalymene duplicata* do not point forward ; and, except towards the lateral extremities, this also applies to the course of the posterior marginal furrow. *P. éire* shares with *P. duplicata forma femina* the tendency for the front part of the axial furrows to be wider. The glabellar furrows are more oblique in *P. éire*, but this and anterior pointing of basal glabellar lobes are more marked in internal moulds. In *P. duplicata* the pre-ocular branches of the facial sutures converge forwards throughout most of their length, but in *P. éire*, much as in *Reacalymene pusulosa* Shirley, it is only the front parts which converge. *R. pusulosa* has different sizes of granules on the raised anterior border, quite like *P. duplicata*, but the pre-glabellar field is narrower than in *P. éire* and is bounded in front by a more angular ridge. The glabella in *R. pusulosa* extends in front of the raised anterior parts of the fixed cheeks.

The glabellar outline of *Platycalymene éire* and the reduction of the first glabellar lobes point towards a trend like that seen in *Flexicalymene caractaci* (Salter), but *P. éire* has no intermediate lobation between the basal and second glabellar lobes and is also distinguished

by its very oblique glabellar furrows. The lateral glabellar lobes of *F. caractaci* are more inflated, but in *P. éire* we probably see the ancestral condition. *F. aldonensis* (Reed) shows less oblique lateral glabellar furrows and more inflated lobes, along with sharply upturned narrow anterior border and great backward migration of the eyes. *P. tasgarensis* Shirley has the frontal lobe of the glabella and the cheeks narrower than in *P. duplicata*, but not so narrow as in *P. éire*.

Genus FLEXICALYMENE Shirley, 1936

Flexicalymene scotica sp. nov.

Pl. XVIII, figs. 6–7

Diagnosis.—Glabella broad, wider than long, rising above cheeks, and strongly and evenly inflated from back to front and from side to side. Basal glabellar lobes rounded, inflated, each one-third of basal width of glabella. Third lateral glabellar furrows transverse but continued obliquely backwards behind intermediate lobes. Large rounded second lateral lobes bounded by oblique furrows in front and separated from axis of glabella by shallow wide longitudinal grooves. First lateral lobes very small, rounded, failing by their own diameter to reach general outline of glabella as indicated by outer margin of second lateral lobes. Furrows separating first lateral lobes from frontal lobe very short. Frontal lobe oblong, more than three times wider than long, has straight front margin with slight re-entrant angle on axis, and rises steeply with some overhang above concave preglabellar field. Anterior border is turned up at right angles to a line joining preglabellar field to occipital ring. Occipital ring bends upward and forward over axis, is not lobate but laterally is about a third as long as the basal glabellar lobe in front of it.

Axial furrows are convex outwards, wide, with slight constriction opposite second and third lateral glabellar furrows and occipital furrow ; widest beside small first lateral lobes. Cheeks inflated, but lower than glabella, extend as far forward as front of glabella and overhang the lateral prolongation of the preglabellar field. Palpebral lobes rise high in line with front part of second glabellar lobes and small first lobes. Anterior branches of facial sutures converge slightly in front, but the anterior border measured from side to side is very broad. It rises evenly over median line and is somewhat convex forwards. Posterior branch of facial suture diverges sharply outwards almost at right angles to the anterior branch.

Dimensions.—Length of cranidium, 12·0 mm. (approx.) ; length of glabella, 8·5 mm. ; width of glabella across basal lobes, 10·5 mm.

Holotype.—Lamont Collection, No. 32.

Horizon.—High Mains Sandstone (? Hirnantian).

Locality.—Small grassy knoll, 100 yards west of High Mains farmhouse, north-west of Dailly, South Ayrshire.

Remarks.—It will be seen that this species has affinities with *Flexicalymene meeki* (Foerste) of the Cincinnatian and with *F.* cf. *meeki* (Lamont) (1935, Pl. VIII, figs. 10–11 ; Shirley, 1936, Pl. XXIX, fig. 8) from the Lower Drummuck Group, but *F. scotica* differs in the much shorter first lateral glabellar lobes and in the emarginate flattened outline of the anterior part of the broad frontal lobe. *F. quadrata* (W. B. R. King) is distinguished by greater inflation of the anterior part of the glabella as seen in profile (Shirley, 1936, p. 391, fig. 2) and by almost equal-sized first and second glabellar lobes.

Though possessing no buttress, *Flexicalymene scotica* has much the same inconspicuous first lateral lobes as *Calymene planicurvata* Shirley from the Upper Llandovery. In neither of these species do the glabellar lobes " stand out from the general outline " as Shirley puts it. In *C. planicurvata*, however, the frontal lobe is longer and rounded anteriorly and the anterior part of the glabella rises higher above the preglabellar field than in *F. scotica*, in which maximum convexity of the profile is seen at a position between the second lateral lobes.

Flexicalymene is mainly an Ordovician genus, but it has been recorded in the Silurian, as for example by E. D. Gill (1945, p. 182). Taken in conjunction, however, with a form of *Hirnantia sagittifera* (McCoy) that occurs in the High Mains Sandstone, it may indicate a high Ordovician horizon such as Hirnantian (cf. Lamont, 1935).

Genus CALYMENE Brongniart, 1822

Calymene hadyardensis sp. nov.

Pl. XVIII, figs. 8–12

Diagnosis.—Cephalon sub-triangular, rounded in front. Preglabellar field narrow, very slightly concave, nearly parallel to plane of rest of dorsal shield. Anterior border not thickened, except opposite anterior ends of axial furrows, where a row of about three small tubercles may be carried. Glabella bell-shaped, almost as long as broad. Occipital ring longest over axis, where it is massive, strongly arched forward and upward, with sharp pustule on anterior border and two widely spaced pustules on each side, narrow laterally with incipient elongate lobe pointing obliquely forward. Basal glabellar lobes projecting, well rounded, inflated, connected by short necks sunk below general level to axial part of glabella. Third lateral furrows transverse, deep, turning back, and then with short shallow transverse continuation, so outlining low indistinct intermediate lobes. Second lobes hemispherical, not projecting as far as basal lobes, separated from rest of glabella by longitudinal furrow. First pair of lobes, very short and transverse,

extend laterally beyond outline of frontal lobe which is short, semi-oval, and overhangs strongly in front, with a width little more than half that of the anterior border between facial sutures. Anterior parts of fixed cheeks project beyond first lateral furrows of glabella and overhang carrying two large pustules in front and one behind close to the axial furrow and near where the eyeline, itself carrying two more pustules, begins to run obliquely backwards to the small palpebral lobe. Another pustule appears near the summit of the buttress. The longer axis of the palpebral lobe diverges outwards in front so interrupting the course of the facial suture which behind it swings gently outwards and then runs in a straight line towards the genal angle. The form of the posterior branch of the suture is like that of a question-mark. A group of two or three pustules occur on the free cheek close to the anterior end of the posterior branch of the facial suture. Just in front of the eye the free cheek is folded down sharply at an angle of 90° or more and a few widely spaced pustules may appear along the line of folding. There is a deep rounded lateral marginal furrow, outside which the lateral border, angulate towards the genal extremity, carries a few pustules as we trace it forward, and finally developes a bevel, with sparse tubercles on the inside of the later, before it reaches the anterior branch of the facial suture. The bevel slopes forward and beneath it a strong, shelly shield is formed on the underside of the cephalon which laterally attains a length nearly equal to half that of the fixed cheek behind the eye. Buttress pustulate, rounded rather than angular, comes very close to second lateral glabellar lobes ; axial furrow deep and convex outwards against basal lobes. Very wide posterior marginal furrow. Posterior border flattened distally and covering antero-lateral half of first thoracic pleura.

Thorax of thirteen segments tapers gently in a posterior direction. Axis is one-third of width. Inner and lateral parts of pleurae are roughly equal except in front where the inner parts are relatively longer. Outer parts are flat and nearly at right angles to the convex inner parts. Axial rings show articulating half rings. Lateral parts of first three rings narrow, pointing forwards, slightly lobate with occasional small pustules. Lateral extremities of axial rings 4, 5, and 6 are more flattened and carry pustules which increase in size as we follow them backwards. Posteriorly the extremities of the axial rings are narrower again, but the pustules become short spiny processes pointing obliquely upwards and outwards, diminishing on rings 12 and 13. The posterior bands of pleurae are twice as long and more convex than the anterior bands. Outside the fulcrum the posterior bands become still longer and flattened, except for a posterior ridge which sweeps forward in a gentle curve providing a raised margin for the flattened anterior part which merges with the anterior band. On

some of the posterior thoracic segments, however, a fine incised line continues to separate the distal parts of the anterior and posterior bands.

Pygidium is roughly triangular, with six axial rings, rapidly decreasing in breadth, distally curving forward round shallow appendifer pits to terminate pointing obliquely forward in slight swellings, one or two of which carry tiny pustules, above broad axial furrows. A post-axial swelling is separated by a marked transverse furrow from the rest of the rachis. Five pleurae seem to be present with occasional pustules. At decreasing distances from the axis, as we go in a posterior direction, the first four pairs of pleurae are flexed backwards and bent downwards and inwards towards the underside. Fifth pair of pleurae short, nearly parallel to axis.

Dimensions.—Length of cephalon, 6·5 mm.; width of cephalon, 15·0 mm.; length of glabella, 5·5 mm.; width of glabella across basal lobes, 6·0 mm.; length of thorax, 14·0 mm.; length of pygidium, 4·0 mm.; width of pygidium, 7·0 mm.

Holotype.—Grant Institute of Geology Collection.

Paratype.—Lamont Collection, No. 33.

Horizons.—Bargany Pond Burn Group (Lower Gala) and Penkill Group (Lower Gala).

Localities.—North side of Hadyard Hill, south-west of Dailly (holotype); Penwhapple gorge, near Penkill Castle (paratype).

Remarks.—Small spines on lateral parts of axial rings towards posterior end of thorax may have served to discourage attack while the front part of *Calymene hadyardensis* was submerged in mud. From the figure in Pl. XVIII, fig. 11, the tendency for arching up of the posterior part of the thorax will be seen. The sharp downward bend of the pygidium recalls the condition in a specimen attributed to *Calymene subdiademata* McCoy (1851, pp. 166–7, Pl. 1F, fig. 10*a*) from Coniston Waterhead. The specimen which should be treated as type was figured from Leintwardine (fig. 9 and 9*a*), but appears to have been lost. Shirley suggests (1933, p. 65) that *C. subdiademata* is a *nomen nudum*, but the present writer can hardly agree as it seems to apply to a species resembling *C. hadyardensis* but differing in a more thickened and upturned anterior border.

The maximum convexity in a longitudinal profile of the glabella of *Calymene hadyardensis* is on a line joining the first lateral glabellar lobes (Pl. XVIII, fig. 11), but this has been over-emphasized by slight damage to the specimen, due to some projecting hard body inside—possibly the hypostome.

The projecting basal lobes of the glabella remind one of the condition in *Calymene camerata* Hall from the Coralline Limestone, at Schoharie,

New York State. A similar condition is also seen in *C. carlops* sp. nov., more especially in young specimens (Pl. XVIII, fig. 18).

The nearly flat preglabellar field and border in *Calymene hadyardensis* comes as a surprise in a characteristically Silurian form. It probably indicates adaptation to shallow burrowing probably in search of food or when eggs were being laid.

As well as the pustules on the cheeks a few appear to have been distributed on the frontal and basal lobes of the glabella, but the state of preservation renders them unclear, though part of the original exoskeleton where preserved seems to have had a coppery-red hue.

Calymene carlops sp. nov.

Pl. XVIII, figs. 13–19

Diagnosis.—Cephalon triangular, rounded in front ; strongly convex from front to back ; convexity from side to side forming an arc of a circle over the glabella but with somewhat flattened lateral parts of cheeks projecting beyond this. Glabella bell-shaped, longer than wide, with basal lobes protruding up to about half their diameter beyond second lateral lobes. Maximum curvature of longitudinal profile at or just in front of first lateral lobes. Front half of frontal lobe with semi-oval outline, slightly emarginate, overhangs most on either side, less on axis where a longitudinal rise crosses the preglabellar field. Sparse larger pustules among smaller ones, sometimes connected by fine raised lines, are seen especially on the front part of the glabella and on its lateral lobes, also on the pointed anterior parts of the fixed cheeks and on the upturned anterior border. Sides of the frontal lobe are parallel and high above axial furrow carry traces of small additional lobes (" fourth lobes " of Shirley) in front of the vertically elongate, slightly projecting first lateral lobes. Anterior pits in axial furrows against parallel sides of frontal lobe ; smaller pits nearly opposite first lateral lobes. Larger, more protuberant second lateral lobes, separated from median part of glabella by shallow semi-circular depressions, overhang the axial furrows as much as do the sharply cuspate buttresses opposite them. Basal lobes prominent, connected to glabella by depressed " necks ". They carry four or five fairly large ill-defined pustules. Occipital ring convex, massive, very long over axis, rounded ; narrower and slightly flexed forward at sides. Posterior part of axial furrow overhung by the basal glabellar lobes but not by steeply rising posterior part of fixed cheeks. Palpebral lobes opposite front part of second lateral lobes. Facial suture behind palpebral lobes curves in a little before turning outwards at right angles to glabella. Anterior branch of facial suture at first parallel to glabella, then concave towards it, before it meets swollen lateral extremity of sharply upturned anterior border which is bent back so as to overhang the

deeply excavated lateral areas of the preglabellar field. Just inside the suture a longitudinal rise connects the anterior border with the steep anterior parts of the fixed cheeks. On each of these a short ridge runs obliquely backwards towards the posterior part of the palpebral lobe which is continued backwards in a narrow elevation behind the palpebral lobe.

Thorax unknown.

Pygidium with prominent, tapering axis, occupying fully one-third of width in front, with five or six rings and narrow posterior axial ridge separated off by shallow transverse furrow that is rounded but not so deep as the axial furrow which deepens and becomes wider anteriorly. Four oval appendifer pits on either side occur between the first five rings of the rachis, followed posteriorly by very weak indications of pits. Median tubercles on first two rings of axis. Four pairs of pleurae are bent down and quickly turn backwards outside the axial furrows. Pleurae may be furrowed for about half their length from the posterior margin which they meet at right angles, or they may be simple and much narrower than the segmental grooves. One or two pustules, widely spaced, may appear on pleurae. Fifth pair of pleurae short, practically parallel to axis. Rear margin, as viewed from behind, is bent up almost forming a right angle. In dorsal view, from above, it is decidedly emarginate behind the short post-axial ridge which carries a single dorsal pustule.

Dimensions.—

	Lamont Colln.	*R. Scott. Mus. Colln.*	
	No. 34.	*A.*	*B.*
	mm.	*mm.*	*mm.*
Length of cephalon . . .	7·5	5·5	
Width of cephalon	14·0	10·0	
Length of glabella	6·7	4·5	3·3
Width of glabella	5·5	4·0	2·7
	No. 35.		
Axial length of pygidium .	3·5		
Width of pygidium . . .	5·0		

Syntypes.—Lamont Collection, Nos. 34 and 35.

Horizon.—*Plectodonta* aff. *canastonensis* siltstones, Pentlandian (Upper Gala).

Locality.—Deerhope, north of Carlops, Pentland Hills.

Remarks.—In North America the Niagaran *Calymene celebra* Raymond is related to *C. carlops*. It has the same type of pygidium which may have been derived by a simplification of a form like that in *Platycalymene* (Pl. XVIII, fig. 5). *C. carlops* has the frontal lobe of the glabella broader and the anterior border is wider and curves back to a greater degree laterally. In the last respect there is resemblance to *C. antigonishensis* McLearn, which, however, has the anterior border

swollen more as in *C. intermedia* Lindström from the Wenlock and (*fide* Shirley, 1933, p. 64) Aymestry Limestone and Kirkby Moor Flags. McLearn (1924, p. 163) reports his species from the McAdam (?), Moydart, and Stonehouse formations of Nova Scotia. He spreads out these formations from Woolhope to "Upper Ludlow", but the McAdam may correlate with the Pentlandian and the Moydart and Stonehouse not be as late as he believes.

Calymene laevis Lindström has longer bell-shaped glabella and narrower frontal lobe, but as in *C. carlops* small "fourth" lobes appear (1885, Pl. XVI, fig. 5). Closest akin to *C. carlops*, however, seems to be *C. frontosa* Lindström, which comes from the oldest beds of the Marlshales, near Wisby, and which differs mainly in having a more tapering and shorter frontal lobe of the glabella which is also more strongly papillate than the Pentland specimens. A similar difference in ornament holds between *Cyphoproetus* (*Carlopsia*) *glaudii* Lamont from the Pentland Hills and the strongly pustulate *Cy. punctillosus* (Lindström) from Gotland. H. Munthe (1910, pp. 1399–1400) places the Marlshales just above the Stricklandia Marl of the Wisby district, which he treats as Upper Llandovery. He correlates the Marlshales with the Wenlock Shale, but they may be somewhat older and seem to have a good deal in common with the Pentlandian, including brachiopods like *Stropheodonta walmstedti* (Lindström) which occurs along with *C. carlops* in the lower part of the *Plectodonta* aff. *canastonensis* beds at the Deerhope and high up on the south side of Wetherlaw Linn.

Calymene blumenbachii Brongniart has the axial furrows less wide and less deeply excavated under the overhanging glabellar lobes and anterior parts of the fixed cheeks. It has the glabella wider in front and coming closer to the anterior border, while the glabellar surface is more abundantly, more finely, and more uniformly papillate. In the pygidium the ribs show more uniform development of pleural furrows and diverge laterally for some distance before they gradually turn backwards. *C. lata* Shirley (Wenlock-Lower Ludlow) has maximum inflation of the glabellar profile further forward than in *C. carlops*, also more uniform and abundant fine pustules, and less sudden retroflexion of the ribs on the lateral lobes of the pygidium. Such differences may be used as evidence of the pre-Wenlock age of the fauna which includes *C. carlops*. It may be added that in the Blair and Straiton beds at Knockgairdner, in S. Ayrshire, the *Calymene* present is not *C. blumenbachii* as stated by Peach and Horne (1899, p. 550) but in all probability *C. carlops*.

Thanks are due to the Senate of the University of Edinburgh for the award of a University Research Fellowship during the preparation of this paper.

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EXPLANATION OF PLATE

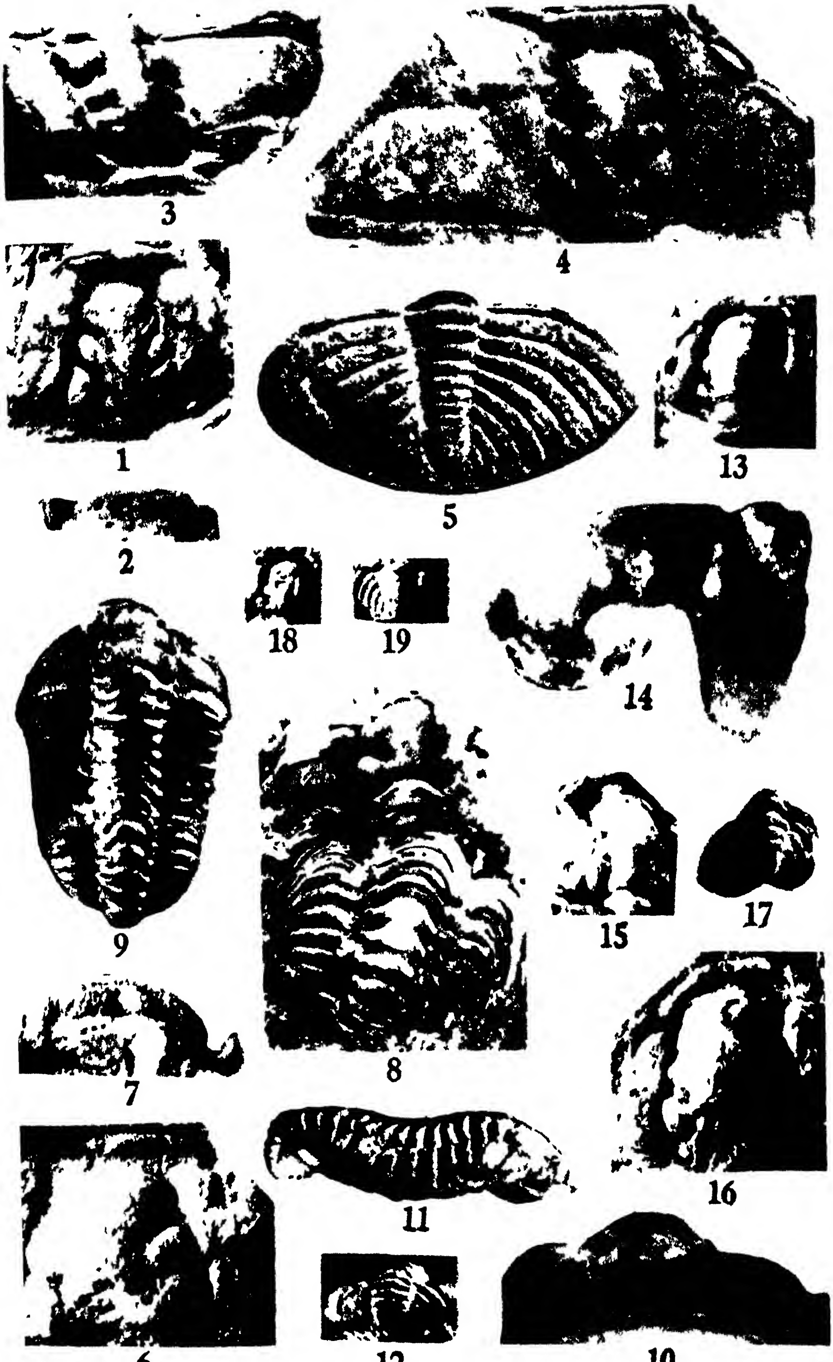
FIG. 1.—*Platycalymene éire* sp. nov. Internal mould of cranidium. Tramore Limestone Stage 3, Newtown Glen. × 2 (Lamont Colln. No. 36).

FIG. 2.—Ditto. Longitudinal profile. × 2.

FIG. 3.—*Platycalymene duplicata* (Murchison) *forma femina* (Salter). Cranidium showing two pits in each axial furrow at proximal ends of eyelines, these pits not corresponding with the first lateral furrows of the glabella. *Forma femina* is broader across the basal glabellar lobes than Salter's *forma mas*. Quarry south-west of Llan Fawr, Llandrindod Wells. × 2 (Chamberlain Colln., 144/32, Birmingham University).

FIG. 4.—*Platycalymene duplicata* (Murchison) *forma mas* (Salter). Internal mould of cranidium with two pairs of anterior pits. Glabella relatively narrow as measured across basal lobes. Llan Fawr Quarry (*Nemagraptus gracilis* beds). × 2 (Lamont Colln., No. 37).

FIG. 5.—*Platycalymene duplicata* (Murchison). Internal mould of pygidium. Same locality and horizon. × 2 (Lamont Colln., No. 38).



New Species of Calymenidae from Scotland and Ireland.

FIG. 6.—*Flexicalymene scotica* sp. nov. Internal mould of cranidium. High Mains Sandstone, 100 yards west of High Mains farmhouse, Dailly. × 2 (Lamont Colln., No. 32).
FIG. 7.—Ditto. Longitudinal profile. × 2.
FIG. 8.—*Calymene hadyardensis* sp. nov. Partly decorticated cephalon and thorax. Posterior thoracic segments have short spines at lateral ends of axial rings. Impure limestone, Penwhapple Gorge, Penkill. × 2 (Lamont Colln., No. 33).
FIG. 9.—*Calymene hadyardensis* sp. nov. Internal mould of complete dorsal shield. North side of Hadyard Hill, south-west of Dailly. × 2 (Grant Institute of Geology Colln.).
FIG. 10.—Ditto. Anterior view. × 3.
FIG. 11.—Ditto. Profile. × 2.
FIG. 12.—Ditto. Pygidium. × 2.
FIG. 13.—*Calymene carlops* sp. nov. Internal mould of cranidium. *Plectodonta* aff. *canastonensis* siltstones, Deerhope, Pentland Hills. × 2 (Lamont Colln., No. 34).
FIG. 14.—Ditto. Longitudinal profile. × 6.
FIG. 15.—*Calymene carlops* sp. nov. Internal mould of small cranidium. Same horizon, high on south-west side of Wetherlaw Linn. × 3 (Grant Institute of Geology Colln.).
FIG. 16.—*Calymene carlops* sp. nov. Internal mould of cranidium. Same horizon, Deerhope. × 3 (John Henderson Colln., 1876, 42/6*A*, R. Scottish Museum).
FIG. 17.—*Calymene carlops* sp. nov. Internal mould of pygidium. Same horizon and locality. × 2 (Lamont Colln., No. 35).
FIG. 18.—*Calymene carlops* sp. nov. Internal mould of small cranidium. Same horizon and locality. × 2 (John Henderson Colln., 1876, 42/6*B*, R. Scottish Museum).
FIG. 19.—*Calymene carlops* sp. nov. Internal mould of small pygidium. Same horizon and locality. × 2 (John Henderson Colln., 1876, 42/6*C*, R. Scottish Museum).

CORRESPONDENCE

MAGMA TYPES

SIR,—The recent paper by Mr. M. K. Wells and Dr. A. K. Wells on Magma Types (*Geol. Mag.*, 1948, p. 349), and the letter thereon by Professor A. Holmes (*Geol. Mag.*, 1949, p. 71), have caused me to consult my own use of the term. This occurs in my paper " On the Basaltic Lavas penetrated by the Deep Boring for Coal at Bhusawal, Bombay Presidency ", *Rec. Geol. Surv. Ind.*, liii, p. 196 (1925). This paper was written in Calcutta during the recess period of 1924, so that my use of the term " magma-type " was made in ignorance of its use by the authors of the Mull memoir published in the same year, to which, consequently, I make no reference.

As a result I find that I have used the term with a significance somewhat different from that of the Mull memoir. My paper contains a record, with description of the mineralogy and petrology, of 1,171 feet vertical of horizontal basaltic lavas of the Deccan Trap formation pierced in a deep bore-hole for coal. The study of the cores showed that twenty-nine flows had been cut, and that the range of thickness of the twenty-seven flows completely pierced was from 5 feet to 97 ft. 3 in., with an average thickness of 40 feet. No analyses were made of these rocks, but from the microscope study, making use of mineralogical and other peculiarities, it was possible to arrange them into seven groups based on the absence or presence of phenocrysts of olivine and labradorite, and on whether these had remained suspended in the flow or had sunk towards the base. These seven groups were made into two types according to peculiarities exhibited by the iron-ores ; and it was these two more comprehensive groups that were designated magma-types, on the hypothesis that they had come from different magma-sources.

Sub-crustal and intercrustal magma-basins are discussed on the assumption that these basaltic rocks had come as liquids from subterranean sources, often carrying in suspension phenocrysts of labradorite and olivine of intra-telluric origin. The evidence was held to show that the difference between the porphyritic basalts with phenocrysts of labradorite and olivine and non-porphyritic basalts was entirely due to gravitative settling within a magma-reservoir, and I did not find any evidence for the hypothesis that the olivinic and non-olivinic basalts came from different ultimate sources. My two magma-types each include porphyritic and non-porphyritic basalts. It may be that chemical analysis would show that these two types have no wide-reaching special significance. I do not see why they should, as I attribute all these Deccan Trap effusions to the same ultimate source, namely my infra-plutonic eclogite shell.

Professor Holmes may already know the answer to the question whether there is any significant difference chemically between my two magma-types, since many years ago he asked for, and was I believe supplied with, specimens of my Bhusawal basalts for purposes of chemical study.

Yours faithfully,

L. L. FERMOR.

24 DURDHAM PARK,
BRISTOL, 6.
2nd July, 1949.

EAST ANGLIAN DRIFTS

SIR,—It is distinctly hard on Mr. Baden-Powell that the evidence which led to my East Anglian views should have been produced, and illustrated, in London so soon after his letter was written. For that reason it would be unfair to take his attitude as final, and futile to start a discussion until that evidence, notably as to Corton and Hoxne, is published and can be assessed.

In the meantime may I make a general comment, addressed not so much

to Mr. Baden-Powell, as to all those who oppose this Undermelt Theory and the conclusions arising therefrom. Since the gage has been thrown, their task is to defend the orthodox view that here in Northern England we had a series of ice advances and retreats, the latter marked by extra-glacial sedimentations which may or may not be of Interglacial rank, but do at any rate indicate periods of deglaciation. What they have to show, therefore, is that all the peculiarities of the laminated clays, silts, and sands within the drifts of that area can be matched in unquestioned lacustrine, estuarine, or marine deposits which are preferably, though not necessarily, built up from the erosion of Glacial detritus : *all* is the operative word, please. But that is not the end, for they then have to account for the till-on-sand contacts and " roof-falls ", as I call them, harmonizing them with forward ice-movements. If they would wait until the new evidence of which I have spoken is published, they would then have all the data before them, and could go ahead secure in the knowledge that no further mines are to be sprung in their path.

In this matter, I do not take my stand on being partly right, but on being wholly right. There was in Britain but one great glaciation—the Saale, or Mindel of the Alps : the rest were but small mountain affairs. Rarely in geology has there been an issue so clear-cut as this. In truth, there is no room here for that compromise so dear to the British mind, or even for that which is so dear to the professional mind, the making of a simple thing complicated. And the curious-minded will find a commentary on the situation as a whole on page 198 of W. B. Wright's *Quaternary Ice-Age ;* the first edition, not the second. Subject apart, what he had to say serves to admiration our present business.

R. G. CARRUTHERS.

HIGH BARN,
STOCKSFIELD ON TYNE.
20th July, 1949.

REVIEWS

GEOLOGY OF THE NORTHERN PENNINE OREFIELD. Volume I. Tyne to Stainmore. By K. C. DUNHAM. Memoir Geological Survey of Great Britain, pp. 357, with 33 text-figures and 4 folding plates. 1948. Price 17*s.* 6*d.*

This admirable volume is based on a war-time reinvestigation of the mineral deposits of the Northern Pennines by an author pre-eminently fitted for the task. It deals mainly with the area of Carboniferous rocks extending southwards from the Tyne valley to the Stainmore gap, between Barnard Castle and Brough, a region once famous for its lead mining and still an active producer of barytes, witherite, and fluorspar.

A brief outline of the history of mining is followed by a lucid account of the stratigraphical succession, with its remarkable repetitions of rhythmic series, or cyclothems, in the Middle Limestone Group of the Carboniferous Limestone Series, and by a short description of the igneous intrusions, notably the Whin Sill and related dykes. The gentle asymmetric dome structure of the Alston Block is well illustrated by a map which not only shows contours on the base of the Great Limestone, but also displays the perfect conjugate pattern of the vein-fissures throughout the orefield. These fissures, associated with normal faulting, typically steepen and widen out in the harder beds, and since the tearing-apart of their walls is probably due to tension resulting from domal uplift, it unfortunately follows that the width of openings propitious for ore deposition must diminish as the veins are followed in depth—an inference borne out by past mining operations. Owing to their physical response to fracturing, the hard limestones, dolerite,

and sandstones are particularly congenial as hosts to vein oreshoots, and within the limestones and Whin Sill these shoots may be widened by replacement of the wall-rocks. The other type of ore deposits, the metasomatic flats, are formed by the replacement of flat-lying favourable limestones and are always accompanied by feeding channels. Frequently the flats appear to have developed where the formation of vein oreshoots was inhibited, and elsewhere they are localized along gentle anticlines.

Descriptions of the primary minerals, notably lead and zinc sulphides, fluorite, barite, and various carbonates, are followed in turn by valuable accounts of their zonal distribution, the nature of wall-rock alteration in different kinds of country rock, and the effects of secondary, oxidation processes. Then, in a statement on the nature of the mineralizing solutions and the origin of the deposits, the author concludes that a hydrothermal derivation most adequately explains the primary mineralization of the Northern Pennines, a conclusion that few are likely to dispute. No decisive evidence is yet offered to settle the vexed question as to the exact age of the hypogene mineralization. After citing arguments in favour of Permo-Carboniferous (Hercynian) and Tertiary ages, it is suggested that in view of the widespread fluorite-barite replacements of the Lower Magnesian Limestone a post-Lower Permian age seems probable, and that cogent reasons may still be forthcoming to clinch the case for a Tertiary date.

More than 200 pages are " devoted to descriptions, by areas, of the details of mineral deposits, summarizing the wealth of information which has been collected during the re-examination of the orefield ". This splendid achievement will for long remain the outstanding reference on the subject, and a much-valued boon to all concerned with the future mineral development of this area, wherein several virgin tracts, particularly in the Great Limestone, are deemed worthy of exploration in the hope of finding new orebodies.

The general excellence of this Memoir will certainly enhance the Geological Survey's reputation for work on economic mineral deposits.

D. W.

A STUDY OF THE STRUCTURE, CLASSIFICATION, AND RELATIONSHIPS OF THE PALAEOZOIC ARACHNIDA. Based on the Collections of the British Museum. By A. PETRUNKEVITCH. Transactions of the Connecticut Academy of Sciences, vol. 37, 1949, pp. 69–315, i–xi, pls. 1–83. New Haven, Conn. Price $7.70.

Some years ago, Ray Lankester separated the Eurypterida and the Xiphosura from the Crustacea, and considered them as orders of the class Arachnida. The author of this excellently illustrated and scholarly memoir is a well-known zoologist who, for some forty years, has specialized among Arachnida, including their fossil representatives. To him, Arachnida form a class of an equal taxonomic grade to Eurypterida and Xiphosura ; the three classes together form part of the Chelicerata, sharing the presence in their members of only six pairs of cephalo-thoracic appendages of which the first pair lie in front of the mouth. The Arachnida differ essentially from the other groups in the absence of compound eyes, and in the possession of lung-books or tracheal tubes instead of book-gills. Professor Petrunkevitch, in a new classification, interprets the class as comprising four sub-classes on the basis of the junction between the cephalothorax and the abdomen, the backward displacement of the mouth, and the position of the proximal joints of the chelicerae. Two of these sub-classes disappeared before the close of the Palaeozoic era. Sixteen orders are now recognized within the four sub-classes, their characters are discussed, keys to families and genera are provided, and evolutionary trends are indicated for some of the structural features, particularly those to be seen in fossils. Here, the author's skill in cleaning the material and in photography become evident ; indeed, his comments on the latter subject are most valuable. He stresses the dangers in interpreting dorsal and ventral abdominal surfaces when these have been

superimposed during fossilization ; he demonstrates instances where, by removing matrix bearing the mould of the inner surface of the dorsal wall, he has exposed the ventral wall ; this technique has led to new discoveries, and caused him to revise not only T. I. Pocock's earlier classification, but the modified version of this which he used himself as recently as 1945.

The present memoir arises from the author's study at Yale of Palaeozoic Arachnida lent to him in 1946 by the authorities of the British Museum (Natural History). In conformity with the regulations of that museum, figured specimens were not lent though some described but unfigured material was made available. The major part of the collection studied came from clay-ironstone nodules found some ten feet above the Thick Coal at Coseley and Dudley in the South Staffordshire Coalfield. These fossils were collected by Messrs. W. Egginton, W. Hind, W. Madeley, H. Johnston, S. Priest, and others. The author's reinforcement and revision of Pocock's work means that now some thirty Arachnid species are known from these beds, and these are classed into twenty-four genera distributed among nine of the twelve orders known to occur in Palaeozoic times. From an approximately similar horizon at Crowcrook in the Durham Coalfield, seven species are described, of which six are congeneric and two conspecific with the S. Staffordshire fauna. Knowledge of the two successively earlier Coal Measure faunas (the supposed Pennystone of Coalbrookdale and the Arley Mine of Sparth Bottoms, Lancashire) has not been materially increased except to change Pocock's generic reference of two species from *Anthroscorpio* to *Eoscorpius*. A small number of Lower Carboniferous specimens were studied, but though they are discussed, none of S. Hirst's genera from the Devonian Rhynie Chert were examined, neither were the two known Scottish specimens of Silurian scorpions. It is good to learn, however, that this year the author is visiting Europe for the purpose of studying the type material of Palaeozoic and other fossil Arachnida, and the publication of further results of this high calibre are awaited with interest.

C. J. S.

THE GEOLOGY OF THE BRITISH EMPIRE. By F. R. C. REED. pp. viii + 764, with 26 folding maps and figures. London : Edward Arnold. 1949. Price 70*s*.

The first edition of this book was published in 1921 : the present, the second edition, was just completed by the author before his death, and was finally passed through the press by Sir Edwin Pascoe, who has also died since its appearance. He disclaims having made any serious alterations in the MS. It is curious to look back upon the changes that the imperial idea has undergone in the last twenty-eight years. In 1921 everybody took the Indian Empire for granted, as one of the brightest jewels of the British Crown. Now it is in a most peculiar condition, an independent republic with some kind of a link within the Commonwealth : Burma is now completely independent : Ceylon a self-governing dominion, and so on. However, the author has perhaps wisely ignored all this and simply revised the existing text, even including Palestine, which is certainly not part of the Commonwealth.

The material originated as lecture notes at Cambridge delivered to advanced students, and it is to be feared that the material in the end ran away with the lecturer. There is always the tendency to add another reference to the bibliography, which in some cases grew to be enormous, e.g. India and Burma, 479 items, Australia, 346, Canada and Newfoundland, 676. These are far too much detail, and a good idea is spoiled by excess. However, some of the shorter chapters on small islands are excellent.

Since most of the components of Gondwanaland were originally included in the book it is of interest to speculate whether the author believed in continental drift. He never seems to speak positively on the subject, but one cannot help feeling that he was a believer, from geological evidence, although he could not bring forward a positive proof. This is the most sensible attitude to take.

R. H. R.

PETROLOGY OF THE NORTHAMPTON SAND IRONSTONE FORMATION. By J. H. TAYLOR. pp. vi + 111, with 7 plates, some coloured, and 10 text-figures. *Mem. Geol. Survey*, 1949. Price 12*s*. 6*d*.

The Northampton Sand ironfield has at present the largest output of any in Britain, having of late years surpassed the Cleveland field, which fifty years ago was an easy first. Now the Northampton field yields more than half of the British production. It has been worked from Stowe and Blisworth in the south of Northamptonshire to the city of Lincoln, a distance of about eighty miles, and in places it is about twenty miles wide. But by no means all stone is workable. The best type is described as the main oolitic ironstone group : the predominant feature of this group is the presence of carbonate in the groundmass. This is generally siderite, less commonly calcite. When fresh and unweathered these rocks are bright green, but are commonly weathered brown or yellow anywhere near the surface, and " boxstone " weathering is very common. Altogether five types of ironstone are recognized, but other types are not generally worked.

There is now no doubt whatever that the iron of the rock is an original constituent : the idea of replacement, either as supposed by Sorby for Cleveland, or as postulated by Cayeux for Lorraine, is now completely abandoned. It is probable that it is now held only by Déverin, a Swiss disciple of Cayeux, who recently described on these lines some ferruginous oolites in the " Dogger " (Middle Jurassic) of Switzerland.

It is now generally believed that iron oolites are of marine and shallow water origin, the sources of the iron being various, possibly from the Lias or Trias in the case of Jurassic ores, most of which are very much alike, in a broad sense, i.e. they all include a great variety of types, which are repeated over and over again, in different occurrences.

This memoir is illustrated by some very successful coloured plates which show the point just noted : in fact, these plates would do just as well to illustrate the ores of the Yorkshire Dogger, which are just about of the same age (Yeovilian to Aalenian), whereas the Northampton ores are probably all Middle Jurassic. A notable and newly described feature in both is what are now called " spastoliths ", i.e. distorted ooliths, showing that these existed for some time in a gelatinous form.

A large part of this memoir is occupied by the study of the exact composition of the different ores from the point of view of beneficiation, i.e. improvement for purposes of ore-dressing and smelting. Another volume on the stratigraphy of the ironstone will appear later.

R. H. R.

THE GEOLOGY OF LINCOLNSHIRE. By Professor H. H. SWINNERTON and Dr. P. E. KENT. Lincolnshire Natural History Brochure No. 1. 1949. 126 pp., 22 figs., 1 plate, 1 folding plate. Published by the Lincolnshire Naturalists' Union, and obtainable from the Hon. Secretary, Linc. Nat. Union, City and County Museum, Lincoln. Price 5*s*. 6*d*., post free.

Part of this useful account of the geology of Lincolnshire is written for beginners ; but the authors have incorporated in it summaries of their recent work. For instance, among other topics, Professor Swinnerton deals with the lower Cretaceous, and Dr. Kent with the Lincolnshire Limestone and with the underground structure of the area. A few of the important fossils are figured ; the variation in facies and lithology of the Jurassic and Cretaceous are well illustrated by diagrammatic sections.

A. G. B.

LES GRAPTOLITHES ET QUELQUES NOUVEAUX GROUPES D'ANIMAUX DU TREMADOC DE LA POLOGNE. By ROMAN KOZLOWSKI. *Palaeontologia Polonica* (Warsaw), iii, pp. xii + 232, with 66 text figures and 42 plates. 4to. No price. (The title page bears the date 1948, but a printed slip attached states that distribution commenced July, 1949.)

Professor Kozlowski's monograph on the Tremadocian graptolite fauna of Wysoczki has been eagerly awaited since the publication of his " Informations préliminaires " in 1938 (*Ann. Soc. Zool. Polonici*, xiii). How the completed manuscript, partly in proof, survived the destruction of Warsaw and the German occupation makes fascinating reading ; the plates were prepared in Sweden from negatives stored in Paris throughout the war ; and Professor Kozlowski is indeed to be congratulated on the successful conclusion to his long labours. The illustrations, particularly the 42 quarto plates of the author's drawings, are magnificent ; and the text, scholarly and well-documented, is palaeozoology at its best. Professor Kozlowski has here done for the graptolites what Professor Stensiö did in 1928 for the Ostracoderms ; and it is not too much to say that with the appearance of this work, the study of the graptolites enters on an entirely new phase. For indeed the work has a value out of all proportion to the magnitude and probably local character of the fauna : all the forms described are new and may possibly never be recognized outside Poland, but the conclusions that have been elicited from their study are of a fundamental importance, and will furnish the means of interpreting other and less remarkably preserved material elsewhere.

The material has been derived from three of forty-six thin chert bands occurring in some sixteen metres of fine-grained glauconitic sandstone exposed in the quarry at Wysoczki about 120 miles south of Warsaw. The chert, filling ripple-mark troughs and irregularities in the underlying sandstone surfaces, is clearly syngenetic. The fauna, in which calcareous organisms are conspicuously absent, includes two horny brachiopods indicating an age equivalent to the *Ceratopyge* Limestone of Sweden, some fifty species of graptolites (all new) and representatives of several new groups of doubtful affinity. It is an attached, benthonic fauna, contrasting strongly with previously described Tremadocian graptolites ; but to what the organisms were attached is by no means clear. What will amaze most readers, familiar by repute with the results obtained, is the extraordinarily fragmental nature of the material, most fragments being only two or three millimetres in length.

Professor Kozlowski has already given (1938) a brief summary of the essential branch structure of the Dendroidea with its stolon system and regular triad budding on the " Wiman rule " into stolothecae, autothecae and bithecae, together with some account of the histology of the periderm, comprising fusellar and cortical layers. He has also (*Biol. Reviews*, 1947) provided an excellent summary of his views on graptolite affinities. The corresponding sections of the monograph, therefore, on morphology and affinities, while giving much-appreciated detail (including the first real account of dendroid ontogeny even exceeding in detail what has been done for the Graptoloidea) have necessarily lost something of their novelty. What the reader will probably turn to most eagerly will be the sections dealing with the morphology of the new Orders and of *Eocephalodiscus*, and Kozlowski's brilliant analysis of the organization of the graptolites and the probable nature of the graptolite animal itself. Since it may well be some time before the monograph is generally available, an abstract of these sections may not be unwelcome.

The most general cause of dimorphism in animals is sexual, and although colonial organisms are commonly hermaphrodite, male and female zooids are known both in *Rhabdopleura* and *Cephalodiscus*, the males in *C. sibogae* being reduced and with almost atrophied brachial apparatus. Kozlowski interprets the bithecae as representing such males, the reduced arms being reflected in the universal absence of apertural processes in bithecae. The autothecae housed the females and in several genera have furnished traces of

embryos. The disappearance of bithecae in Graptoloidea represents a transition to hermaphroditism, corresponding to a better adaptation to colonial life, autothecal females becoming hermaphrodite and bithecal males being eliminated. It is possible that in some early graptoloids with small bithecae, the autothecal individuals were already hermaphrodite and the bithecal zooids non-functional; and in certain Camaroidea lacking bithecae there occur what appear to be vestiges of bithecal stolons.

The stolothecae probably did not house separate " stolozooids ", but were secreted by the autozooids at an early stage of development, each autotheca being secreted by the same individual as the stolotheca which preceded it. The general resemblance between bithecae and stolothecae is thus explained on the view that the stolotheca was secreted by an immature individual (autozooid) with pre-oral lobe and tentacles still relatively undeveloped, the bithecae being secreted by male zooids in which these organs never were fully developed. Thus the dendroid colony was composed of two types of individual, autozooid and bizooid, and in typical graptoloids the rhabdosome results from the activity of autozooids alone, related to an unchitinized stolon.

In *Cephalodiscus*, secondary tissue on the outside of the zooidal tubes derives from the mobility of the zooids, which can leave their tubes and creep over the surface of the coenecium. But the laminated cortical layer which occurs almost universally among graptolites as a secondary thickening can only be due to the existence of soft tissue covering the entire colony, for the zooids are attached at the base of the thecal tubes by their stolons. Such an external membrane is known in certain Polyzoa, where it constitutes a direct prolongation of the wall of the upper edge of each zooid. Its presence in the graptolites would indicate a more advanced colonial organization than living Pterobranchs; the zooids, attached at one end by their stolons and by an extra-thecal membrane at the other, could have had but a limited range of movement. A ventral mouth, U-shaped gut, and dorsal anus may be postulated, together with brachial apparatus in the form of tentacles (at least in the autozooids) probably grouped around two arms or in two tufts on account of the pronounced bilaterality of the thecae, especially their apertural modifications.

Minute vesicular bodies present in certain autothecal cavities (particularly occluded thecae) in some camaroid and tuboid species are interpreted as eggs and packets of embryos, and it is further surmised that the quantity and arrangement of these bodies may imply the division of embryos originally far less numerous, i.e. the peculiar embryonic fission known in certain cyclostomatous Polyzoa. The prosicula corresponds to the larva developed from the egg, with little trace of disc or nema; it would be covered with extra-thecal tissue, later secreting disc, nema, longitudinal strengthening ribs (known only in the Graptoloidea) and probably the spiral line. The absence of disc or nema is no proof of a free-swimming larva, since it may have been attached by soft tissue and such genera as *Phyllograptus* in which no nema has been observed were possibly attached throughout life by a stalk of soft tissue.

So distinct is the metasicula from the prosicula that it must either represent a radical metamorphosis or result from an entirely distinct individual; and Kozlowski favours the view that the prosicular individual was replaced by a metasicular individual, following the degeneration of the former. Again, an analogous process is observable in the astogeny of certain Polyzoa.

Synrhabdosomes in the Graptoloidera are interpreted as a development of colonies by budding or the formation of blastozooids; if this view be correct, the siculae of such rhabdosomes, called pseudosiculae by Kozlowski, should have no prosicula portion. The apex of the pseudosiculae (the base of the pseudosicular individual) must have been comparable with the stolonal node of the Dendroidea and perhaps with the rhizoidal budding of such dendroids as *Syrrhipidograptus*.

Turning now to systematics, the graptolitic material falls into four orders, Dendroidea, Tuboidea, Camaroidea and Stolonoidea.

The Order DENDROIDEA is restricted to forms with chitinized stolons and regular budding on the Wiman rule ; their structure is by now more or less familiar, but the wonderfully detailed account of the astogeny of *Dendrograptus* may be specially noted.

Of the remaining orders, the TUBOIDEA have most in common with the Dendroidea though they are sufficiently distinct to warrant ordinal separation. Bithecae and autothecae are present, essentially as in the Dendroidea, but the stolothecae are much less individualized, forming a system of irregular tubes of variable length with stolons equally variable as to size and structure. In place of the regular triad budding of the Dendroidea, budding here is capricious, the spacing of the nodes and frequency of the thecae being alike variable. Two subdivisions are recognized : Tubidendroid and Tuboid. In the former, typified by *Tubidendrum*, the rhabdosome consists of erect ramifying branches united by bithecae or groups of thecae which become incorporated in the adjoining branch, superficially therefore resembling such a dendroid as *Coremagraptus*. Budding instead of producing triad groups, is more usually diad, with any combination except two autothecae ; the basal part of the rhabdosome is unknown. The second (Tuboid) group comprises more irregular, encrusting colonies whose general appearance is familiar in Wiman's *Galeograptus* and *Discograptus*. Here there is a basal encrusting assemblage of thecae termed the thecorhiza, above which project tubular thecae, singly or in clusters. Stolothecae appear to be entirely confined to the thecorhiza ; autothecae are composed of a basal horizontal part associated with the thecorhiza and an erect, free, distal portion ; irregularly distributed bithecae are sometimes limited to the thecorhiza, sometimes projecting above it along with the autothecae. The sicula and ontogeny remain unknown.

The characteristic feature of the CAMAROIDEA is the autotheca, each composed of two parts as in Tuboids, but here more strongly differentiated into an enlarged creeping portion (camara) and an erect tubular portion (collum) ; owing to the irregularity and extreme tenuity of the peristome, it is concluded that there must have been a gradual transition from the chitinous wall to the soft tissue of the zooid. Stolothecae and bithecae are present in some genera, but in others bithecae are absent (sometimes with vestigial stolons) and the stolothecae are indistinct. In one group there appears something comparable with the thecorhiza of the Tuboidea ; in the other the stolons are embedded in extra-camaral tissue (probably representing highly modified stolothecae) above the camarae. Cortical tissue as such is absent. The development of the colony and its adult form are unknown.

Finally, in the STOLONOIDEA, the distinctive feature is the excessive development and extreme irregularity of the stolon, varying from 50–350μ diameter. Fascicles of stolons or single stolons are often included in stolothecal tubes composed of a thin transparent substance with fusellar structure in complete rings (not half-rings as in the other orders). The thecae produced from stolons, apart from stolothecae, seem all to be of one kind and hence presumably autothecae ; they are rarely preserved intact, and the whole group (which seems of minor importance) is known only by exceedingly fragmentary material.

Quite distinct in structure from these graptolite orders are the two specimens of *Eocephalodiscus*. The more complete coenecium was an irregularly ovoid granule about one and one-half millimetres in longer diameter, with irregular crests and dimples and about a dozen small openings distributed over the surface. It was composed of eleven irregularly curved, more or less tubular cells. In the fusellar structure of the test it resembles the graptolites, but differs from them in the irregular development of the cells, their mutual relations, and the absence of stolons. Most of the cells develop insensibly from part of the cavity of previously formed cells, but three are altogether independent of the others. These must have been formed by buds which detached themselves completely as happens in *Cephalodiscus*, and the cortical

layer of the periderm does not imply the presence of extra-thecal tissue but was probably laid down by zooids moving freely over the surface of the colony. Living *Cephalodiscus* exhibit extremes of variation in the form of the coenecium, which the palaeontologist unacquainted with the soft parts might refer to different genera and families, but which are assigned subgeneric rank by the neozoologist. However, the immense time interval separating *Eocephalodiscus* from *Cephalodiscus*, the limited number of cells, and the fact that the soft parts are unknown, is held to justify the erection of a separate family, *Eocephalodiscidae*.

The Graptovermida, Graptoblasti, and Acanthastida, comprise minute chitinous skeletons of organisms of a highly problematic nature ; the first two are simple, the last-named colonial.

The method of quoting references in the text by serial number is tiresome, for readers familiar with the literature can usually recognize the identity of a paper cited by author and date, whereas a serial number necessitates constant reference to the bibliography. It is also a pity that no diagnoses are given, and misprints are not infrequent. The latter perhaps, and certainly the regrettably poor quality of the paper used in the text, are explained by the conditions of publication of this classic work.

O. M. B. B.

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The Ammonite Genus *Uhligella* in the English Albian [1]

By R. Casey

(PLATE XIX)

Abstract

Uhligella is one of the links between the Hoplitidae and their smooth Desmoceratid ancestors, and occurs typically in the Albian of the Mediterranean Province. Two new species of *Uhligella* found in the Middle Albian of Folkestone provide the first record of the genus in England. Description of the Folkestone specimens is preceded by a discussion of the genus, its circumscription, taxonomy, and systematic position.

I. Introduction

The following pages give an account of two new species of ammonoidea from the Lower Gault and Mammillatum bed (Middle Albian) of Folkestone, both referable to *Uhligella* Jacob. This genus is of considerable interest as providing one of the few known links between the smooth or feebly ornamented Desmoceratidae,[2] dominant in the Mediterranean Province, and their highly modified offshoots, the Hoplitids, so familiar to the student and collector of Gault fossils in this country. In the scheme of phylogeny of the Hoplitidae put forward by Spath (1942, p. 687) *Uhligella* (in a wide sense) is represented as a persistent stock from which diverged successive Hoplitid branches during Lower and Middle Albian time. Like *Desmoceras* itself and the various developments of the fundamental Phylloceratidae and Lytoceratidae, *Uhligella* also characterizes the Albian deposits of Mediterranean regions (Jacob, 1907, p. 391), and judging by present knowledge of its distribution it rarely penetrated to those northerly waters in which were dispersed its more specialized allies. There is no previous record of the genus in England. It appears, however, that one of the species of *Uhligella* described in the present paper was known already to the early investigators of the Folkestone Gault, De Rance (1868) and Price (1874), who seem to have regarded it as a form of *Ammonites deshayesii* (Leymerie MS.) d'Orbigny, an

[1] Published by permission of the Director, Geological Survey and Museum.

[2] Desmoceratidae and Hoplitidae are here used in the familiar sense, complying with the usage of L. F. Spath in his "Monograph of the Ammonoidea of the Gault" (1923–1943). If one accepts the opinion of M. Breistroffer (1947, pp. 59, 83–4) both these family designations must be rejected as invalid according to the International Rules of Zoological Nomenclature.

Aptian species which has since been made the type of the genus *Deshayesites* (Parahoplitidae).

Since *Uhligella* is probably not very well known to the majority of geologists and collectors in this country and has a confused taxonomic record, the paper includes a brief review of the genus.

My thanks are due to Dr. C. J. Stubblefield and Mr. R. V. Melville for allowing me to make use of the collections in their charge at the Geological Survey Museum, where the material formerly in my possession is now deposited. Similar facilities were afforded me at the British Museum (Natural History) by Mr. W. N. Edwards and Dr. L. F. Spath, and at the Sedgwick Museum by Mr. A. G. Brighton. Specimens in the various institutions are indicated in the text by their appropriate registration numbers preceded by the symbol G.S.M. (Geological Survey Museum), B.M. (British Museum), or S.M. (Sedgwick Museum).

II. Systematic Account

Family *DESMOCERATIDAE*

Genus **Uhligella** Jacob, 1907, emend. Breistroffer, 1947

Genolectotype (selected Kilian, 1907, p. 63).—*Desmoceras clansayense* Jacob ; Lower Albian, " Clansayes " horizon (*nodosocostatum* zone). Drôme, S.-E. France (see Jacob, 1905, pp. 403–4).

Uhligella comprises moderately involute, discoidal shells with arched venter and compressed, elliptical whorl-section. Intermittent shallow constrictions are characteristic. The early volutions are costate and are more or less tuberculated around the umbilicus ; with subsequent growth the sculpture gradually fades until the shell attains or approaches the laevigate condition. There is a good deal of variation in the strength and duration of the sculptured stage. In *U. rebouli* (Jacob), for example, the costae are relatively subdued and only the insignificant bullae at their umbilical ends distinguish this form from certain feebly ribbed developments of the Desmoceratid *Beudanticeras*. At the other extreme *U. balmensis* (Jacob) [1] has boldly ribbed and

[1] Concerning this species, Spath (1925, p. 93) writes : " [it] . . . might with propriety be included in *Sonneratia*, although its suture-line is still in the ' *Desmoceras* ' stage." Elsewhere in the same work (pp. 35, 63, 95, 693) it is referred sometimes to *Sonneratia*, sometimes to *Cleoniceras*, either with or without a mark of interrogation. In retaining the species in *Uhligella* I am influenced not so much by the fact that it is connected by a graduated series of passage-forms to *U. rebouli* (Jacob), and thence to *Beudanticeras walleranti* (Jacob), as by its constrictions, suture-line, and Desmoceratid outer whorls. (Compare *U. besairiei* Breistroffer sp., 1936, pl. xv, figs. 17–18, p. 156.) The Californian ammonites included in the group of *Uhligella balmensis* (Jacob) by Anderson (1938, p. 193) belong to a distinct genus for which the name *Coloboceras* Crickmay is available and should be used.

tuberculated inner whorls that are but a step removed from a *Sonneratia* or a *Cleoniceras*, both classified among the early Hoplitidae. Sutural characters are of limited diagnostic value in this group. Generally speaking, the suture-line of *Uhligella* is less simplified than that of *Sonneratia* or *Cleoniceras*, but as in other stocks which show the change from the liostracous to the trachyostracous state, individual species display great variability in the extent to which the septal suture is affected in the process of transformation. Previous authors have pointed out that the degree of symmetry of the principal lobe does not provide a satisfactory means of separating *Uhligella* from *Desmoceras*, as held by Pervinquière (1907, p. 129). Similarly, the disparity in the development of the internal and external portions of the second lateral saddle and certain ontogenetic changes in the relative length of the ventral and first lateral lobes, said by Chaput (1920, pp. 182–3) to characterize *Uhligella*, are not likely to afford much assistance in generic discrimination, since these features are apt to appear in ammonites of similar whorl-shape irrespective of phyletic relationship.

It is improbable that the genus embraces a natural group of species : almost certainly it includes forms that are linked independently to *Beudanticeras*, which according to the belief of Spath (1923, p. 37) cannot be far removed from the stable Phylloceratid root-stock. There are facts, however, which tend to favour the alternative view that *Beudanticeras* is composed, in part at least, of *Uhligellae* which forsook the Hoplitid trend at an early stage in their evolution and reverted to smoothness. Whatever its phylogenetic significance, the approximation of *Uhligella* to *Beudanticeras* on the one hand and to *Sonneratia* and *Cleoniceras* on the other, has always made it difficult to set bounds to the genus and authors have differed widely in their interpretation. Furthermore, there has been a tendency to misapply the name in the literature of the past forty years owing to misconceptions as regards the genotype. When introducing *Uhligella* (as a subgenus of *Desmoceras*) Jacob did not indicate a type-species, the name being applied to three " types principaux ", *D. seguenzae* (Coquand) Sayn sp., *D. zurcheri* Jacob, and *D. clansayense* Jacob, and to a number of *nomina nuda*, *D.* (*U.*) *walleranti*, *D.* (*U.*) *rebouli*, etc. (Jacob, 1907, p. 350). The first citation of a type for *Uhligella* was made by Kilian (1907, p. 63) in the same year, fixing *D. clansayense* Jacob as the type. Jacob's own designation of *D.* (*U.*) *walleranti* as the type of *Uhligella*, although widely quoted by subsequent authors, was not published until the year following (Jacob, 1908, p. 26) and, in any case, is open to objection, since *D.* (*U.*) *walleranti* was not one of the three principal species on which he founded the subgenus. Moreover, it is now agreed that *D.* (" *U.*") *walleranti* Jacob is congeneric with *Ammonites*

beudanti Brongniart, the genotype species of *Beudanticeras* Hitzel. R. Douvillé (1911, p. 218) incorrectly cited *D. seguenzae* (Coquand) Sayn sp. as the type of *Uhligella*, and the same error is made by Roman in his Ammonite Synopsis (Roman, 1938, p. 404). Spath, on the other hand, states that he has used *Uhligella* [*sensu stricto*] for the *zurcheri* group only (Spath, 1942, p. 686).

In the present paper *Uhligella* is adopted with the circumscription given it by Breistroffer (1947, pp. 63–4). Future study will probably show that the pre-Albian forms of the type of *U. seguenzae* and *U. zurcheri*, in which the ribs make no feature at the umbilicus, must be accommodated elsewhere, for they are not strictly congeneric with *D. clansayense* Jacob. The Mexican species " *U.*" *aguilerae* and " *U.*" *jacobi*, described by Burckhardt (1925, pp. 10–12, plate ii, figs. 4–10) represent yet another of these ribbed developments of the Desmoceratidae and the group should be given taxonomic recognition by a reviser who has access to actual specimens.

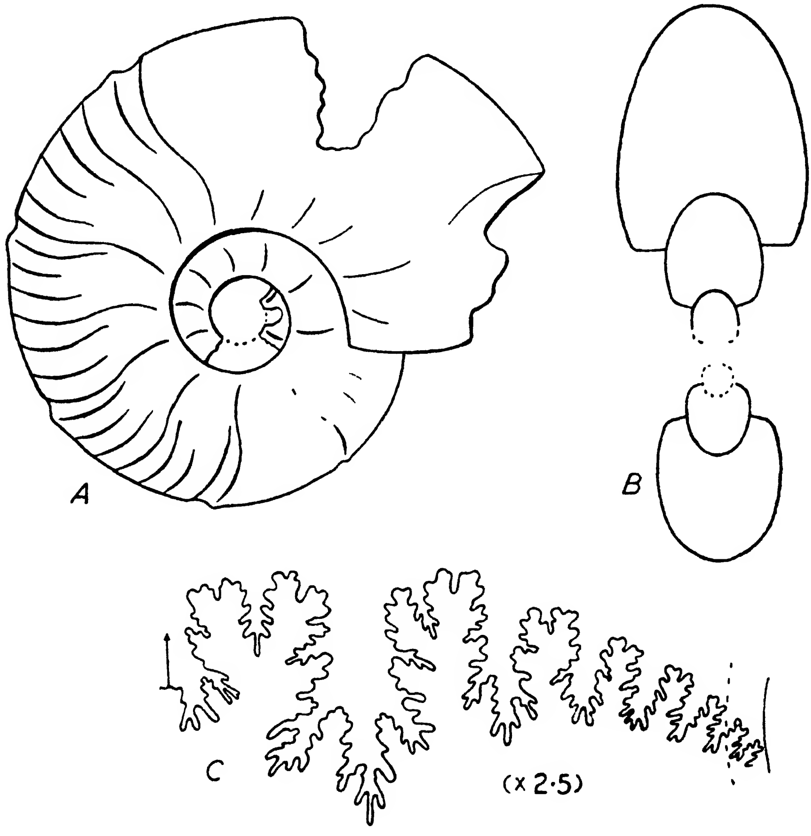
The systematic standing of *Uhligella*, *Lemuroceras*, and other genera which lie on the border-line of the Desmoceratidae and the Hoplitidae, is unsatisfactory, the family assignment being largely a matter of personal approach. The position with regard to *Uhligella* was discussed briefly by H. Douvillé (1916, pp. 370–1), who suggested that on account of its almost obsolete constrictions, tuberculation, and style of ribbing, the genus should be transferred from the Desmoceratidae to the Hoplitidae. Yet in this genus features of Hoplitid affinity are transitory, confined to the early stages of growth, and never become established in the adult, the outer whorls quickly returning to the ancestral, unspecialized condition. The ontogeny of *Uhligella* does, in fact, add to the body of evidence which has accumulated in recent years (mainly through the work of Spath) to show that evolution in the Ammonoidae often proceeded along proterogenetic (coenogenetic) lines ; but the application of this principle to matters of classification has yet to be investigated. In the circumstances it would be considered appropriate, perhaps, to take advantage of the family unit " Cleoniceratidae ", created by Whitehouse (1926, p. 206) for *Cleoniceras*, *Sonneratia*, and other ribbed Desmoceratid offshoots which precede the typical, ventrally sulcate Hoplitidae, and which might be extended to embrace *Uhligella*. Reasons for not adopting this " family " will be stated fully elsewhere : it must suffice for the present to remark that research into the origin and inter-relationships of the early Albian Hoplitidae, facilitated by undescribed material from the English Lower Albian, has made it clear that attempts to detach " Cleoniceratidae " from the main body of the Hoplitidae would increase rather than remove the systematic difficulties. For convenience *Uhligella* is here retained in the family Desmoceratidae.

Uhligella subornata sp. nov.

Plate XIX, figs. 1*a–b* ; Text-fig. 1

Material.—One specimen, G.S.M. 70442 (R. Casey Collection).

Horizon and Locality.—Top of Folkestone Beds (Mammillatum bed). Middle Albian, *mammillatum* zone, *monile* subzone. Foreshore reefs just east of Copt Point, Folkestone.



TEXT-FIG. 1.—*Uhligella subornata* sp. nov. Holotype (R. Casey Collection, G.S.M. 70442). Side view (*A*) and cross-section (*B*) ; with external suture-line (*C*) enlarged × 2·5. Middle Albian, Mammillatum bed (*monile* subzone), Copt Point, Folkestone.

Description of Holotype.—The unique example on which this species is based has the following dimensions :—

Diameter in mm.	65
Whorl-height (in % of diameter) . . .	45
Whorl-thickness (in % of diameter) . . .	35
Umbilicus (in % of diameter)	28

The specimen is an internal mould in black phosphorite, abraded on the side not figured, wholly septate, and with part of the nucleus missing. A scar may be traced along the line of involution for another three-quarters of a whorl, indicating that with the body-chamber the ammonite was at least twice its present size.

The whorls are compressed, progressively increasing in relative height. At a diameter of 40 mm. the cross-section shows the greatest whorl-thickness a little below mid-height and the flattened sides bowed gently outwards in continuity with the curve described by the broadly rounded venter. In the course of growth the point of maximum thickness moves dorsally, the sides become more convergent, the venter in consequence decreases in relative width. At 20 mm. the smooth umbilical wall is high and fairly well turned, though not marked off distinctly from the flanks ; it becomes steeper as growth proceeds, maintaining a rounded border up to about 60 mm. diameter ; thence it becomes perpendicular and angular at the rim.

Costation consists of primary ribs, feebly bullate at the umbilical border in the young, with one to three, generally three, shorter secondaries between the primaries. The irregular union of one or two secondaries with a primary rib is indistinct, since the ammonite tends to smoothness just below the middle of the sides. The primary ribs number twelve to a volution at 40 mm. diameter, but are rather more closely set on the final, degenerate, half-whorl.

Regularly spaced constrictions, about eight per whorl, are confined to the outer zone of the sides and the venter. These constrictions, which are rather strongly marked for the genus, lie between a primary and a secondary rib. The rib preceding the constriction is thickened into a labial ridge and makes a positive feature on the peripheral outline. Otherwise, the ribs are in low relief and, after losing the umbilical bullae, are most pronounced on the ventro-lateral slopes. Ribs and constrictions traverse the flanks in a sigmoidal curve, of which the shortest secondaries complete only the upper flexure, and pass over the venter with a slight forward bend. On the innermost whorls (as revealed in the dorsal area) the ornamentation of the venter is more strongly projected forward. Degeneration of the sculpture sets in apparently from about 20–25 mm. diameter ; at a diameter of 55 mm. the ribs are fading rapidly and at 65 mm. have almost disappeared.

The suture-line has a deep, trifid, asymmetrical principal lobe and markedly dependent auxiliaries.

Remarks.—Uhligella subornata has a close analogue in *U. rebouli* (Jacob), which ranges from the *tardefurcata* to *dentatus* zones in the south-east of France (Jacob, 1908, pp. 32–4, plate xiv (iv), figs. 1–2). That species may be distinguished from *U. subornata* chiefly by its

relatively slender whorls, fainter constrictions, greater involution, and more highly dissected suture-line. Specimens from the Balearic Islands attributed to *U. rebouli* by P. Fallot (1910, p. 78, plate ii, figs. 1–2) agree more closely with the present species in dimensional proportions but have a narrower venter and more numerous and more sinuous primary ribs, in addition to a smoother nucleus.

Uhligella balmensis (Jacob), an associate of *U. rebouli*, has much too robustly ornamented inner whorls to invite comparison with *U. subornata*, and the same may be said of *U. besairiei* (Breistroffer), which also differs markedly in cross-section and coiling, but there are passage forms between *U. balmensis* and *U. rebouli* which have the general aspect of the English species. The resemblance is found to be superficial, however, when actual specimens are examined, the combination of characters being never the same, either the prominent tubercles of *U. balmensis* or the complex lobe line of *U. rebouli* being in evidence.

At a diameter of 40 mm. *U. boussaci* P. Fallot, from Majorca (P. Fallot, 1920, pp. 27–9, plate iii, figs. 3–4), resembles *U. subornata* at a similar size in its broadly rounded venter, nearly parallel whorl-sides and comparatively open umbilicus, but the whorls are not so stout, the ribbing less flexuous and with the primary portion more decidedly elevated and thickened towards the umbilicus. *U. boussaci* is further distinguished by its reduced secondary costation and its simpler type of suture-line, which lacks the markedly dependent auxiliaries found in that of *U. subornata.*

A blunter, coarser style of costation, with fewer secondary ribs to each primary distinguishes *U. clansayensis* (Jacob) from *U. subornata*; there are also dimensional differences.

Beudanticeras dupinianum (d'Orbigny) is a fairly common fossil in the *mammillatum* zone in this country and conceivably might be mistaken for *U. subornata* if badly preserved. It is a more compressed and much less pronouncedly costate species with no tendency towards tuberculation at the umbilical border. The constrictions and accompanying ridges of *B. dupinianum* have a linguiform extension forward on the venter at all stages of growth in contrast to the very feeble forward bend shown in *U. subornata.*

Whether the " *Desmoceras* (*Uhligella*) sp." recorded by the brothers Destombes (1937, p. 102) from the *mammillatum* zone of Wissant, on the French coast opposite Folkestone, belongs to the present species (or even to *Uhligella* as here restricted) is uncertain, the specimen on which the record was based having been lost through enemy action during the late war. (Personal communication from M. J.-P. Destombes.)

Uhligella derancei sp. nov.

Plate XIX, figs. 2*a*–*d*, 3*a*–*b*

1868 *Ammonites Deshayesii* De Rance (*pars*) *non* Leymerie " Albian or Gault of Folkestone ", *Geol. Mag.*, v, p. 167.

1874 *Ammonites Deshayesii* Price *non* Leymerie. " Gault of Folkestone," *Quart. Journ. Geol. Soc.*, xxx, p. 362.

1875 *Ammonites Deshayesii* De Rance (*pars*) *non* Leymerie. *In* Topley, *Geology of the Weald*, p. 436.

1900 *Ammonites Deshayesi* Jukes-Browne (*pars*) *non* Leymerie. *Cretaceous Rocks of Britain*, vol. i, p. 82.

1923 *Beudanticeras subparandieri*, strongly costate variety. Spath, *Monograph Ammonoidea of Gault*, p. 95.

Material.—The holotype (G.S.M. 82908) and one paratype (G.S.M. 74874), both R. Casey Collection, Lower Gault, Bed II (*dentatus* zone, *intermedius* subzone) (*in situ*), foreshore reefs, East Wear Bay, Folkestone, and about five small nuclei from the same locality, found loose or of unrecorded horizon, but all in a mode of preservation consistent with derivation from Bed II. Also a single (decomposing) specimen from Folkestone in the De Rance Collection, Bed II suggested by preservation.

The type specimens, retaining most of the nacreous shell, both terminate at a septal surface. The holotype is complete down to the protoconch and has a small pathological disturbance of the ribbing on the venter at 20 mm. diameter, which does not, however, affect the subsequent formation of the shell. Dimensions are as follows :—

	Holotype (*G.S.M.* 82908).	*Paratype* (*G.S.M.* 74874).
Diameter in mm.	33	28
Whorl-height (in % of diameter) .	46	46
Whorl-thickness (in % of diameter) .	34	36
Umbilicus (in % of diameter) . .	24	23

Specific Description.—Whorl-section compressed, with flattened sides and evenly arched venter, the greatest thickness just above the rim of the umbilicus. Umbilical wall smooth, set nearly perpendicular to the sides, and with an abruptly rounded border, which is surrounded by nine to eleven bullate tubercles. Each bulla corresponds to a falcoid primary rib and two to three crescentic secondaries. The secondary ribs occupy the outer half of the flank, but frequently attempt to join up with the primary root, thus giving the impression of incipient bi- or trifurcation. Ribs continuous across the venter with a sinus forward which becomes less marked in the course of growth. Six or seven very shallow constrictions per whorl, with accompanying feeble bolster ribs, confined to the outer zone of the sides and the venter.

After three smooth serpental whorls the ornamentation is visible (in the holotype) on the umbilical shoulder at the early diameter of

3–4 mm. The ornamentation reaches its maximum vigour between 20 and 25 mm., after which the umbilical tubercles are gradually assimilated by the primary ribs, and the ribs begin to fade from the middle of the sides and on the siphonal line. The tubercles lose definition already at 30 mm. diameter, but available specimens are too small to show the final stages of decline in the ornamentation.

Growth striae across the umbilical rim with an obliquity forwards and thence run parallel with the costae ; they are picked out most easily on the inner third of the flank.

Suture-line simplified, with a deep, trifid, markedly asymmetrical first lateral lobe which tends to undercut the massive external saddle. Ventral and first lateral lobes of equal length at 10 mm. diameter, but ventral lobe eventually reduced in relative length.

Remarks.—This is a rare ammonite in the Gault at Folkestone and appears to be restricted to the *intermedius* subzone (Bed II), which has also yielded isolated examples of *Tetragonites*, *Desmoceras*, and *Brancoceras*—genera which are all typical of Southern European localities. It is my opinion that this is the ammonite recorded from this horizon by De Rance and Price as "*Ammonites Deshayesii* Leymerie". In his paper on the "Albian or Gault of Folkestone", De Rance (1868, p. 167) informs us that "Two distinct forms of *Ammonites Deshayesii* occur in the Lower Cretaceous series, one with a square flat back, the other with a rounded back. The former occurs in the zone of *Rhynchonella sulcata*,[1] and the sand seam in the zone of *Ammonites interruptus* ; the latter form in the Lower Neocomian clay of the Isle of Wight [i.e. the true *Deshayesites* of the (Aptian) Atherfield Clay] and the clay of the Lower Albian [*recte* Middle Albian], zone V [= Bed VII of the standard notation adopted from Price], at Folkestone". A specimen of *U. derancei* in the De Rance Collection (G.S.M. 31346), dated 1868, is labelled as from Bed V [Bed VII] of

[1] De Rance uses this term for the basement-bed of the Folkestone Beds, in which is found the ventrally angular *Hypacanthoplites* of the *jacobi* subzone, not placed on record in this country until over 70 years after the appearance of De Rance's paper ! (See Casey, 1939, p. 365.) A specimen from Folkestone in the Price Collection (G.S.M. 1797), labelled "*Ammonites Deshayesii*", is unquestionably a *Hypacanthoplites* from this very bed. The only ammonites known to me from the sand seam in the zone of "*A. interruptus*" (just above the Pyritic Band at the base of the Gault) are those recorded by Dr. Spath (1943, p. 734, footnote) as "*Hoplites*, including *H. dentatus*" (G.S.M. 83164–6). According to my determinations these ammonites belong to undescribed forms intermediate between *Hoplites* and one of its fore-runners, *Pseudosonneratia*, and would answer to the appellation "*A. Deshayesii*" in the very wide meaning given it by De Rance. The stratigraphical significance of these specimens will be discussed at a later date, but it may be said at once that they indicate a lower horizon than that of *H. dentatus* and that their discovery modifies current views as to the subzonal representation at the base of the Gault at Folkestone.

It is necessary to add that the terms *zone* and *bed* as used by De Rance are interchangeable.

the Gault at Folkestone, though that part of the shell which is not decomposed retains the intense coloration and lustre peculiar to the pyrites-filled ammonites of Price's Bed II. This is the specimen which Spath has referred to as a strongly costate variety of *Beudanticeras subparandieri* (see synonymy). One may surmise that it was obtained from the foreshore reefs, where the dark clays of Bed II and Bed VII are readily enough confused. The true horizon of the ammonite must have been ascertained eventually by De Rance, for in tables showing the distribution of fossils in the Gault at Folkestone published subsequent to his 1868 paper (De Rance, 1875, p. 436 ; Jukes-Browne, 1900, p. 82) *Ammonites Deshayesii* is shown on the authority of De Rance as occurring in Bed II but not in Bed VII. Price also lists the ammonite from Bed II, though it is not represented among the Gault material registered under his name in the British Museum and in the Geological Survey Museum.

Uhligella derancei is an advanced form of *Uhligella* of the type of *U. balmensis* (Jacob) but is less ornate than that species ; it thus resembles some of the transitions between *U. balmensis* and *U. rebouli* mentioned above, particularly the syntype of *U. rebouli* which Breistroffer has designated *U. balmensis* var. *rencurelensis* (= Jacob, 1908, plate xiv (iv), fig. 3). A satisfactory comparison with that variety cannot be made until its inner whorls have been figured, but it is less evolute than the present species and has the complex suture-line of *U. rebouli.* An Escragnolles example in the British Museum (B.M. 37701), similarly transitional between *U. balmensis* and *U. rebouli,* has dimensions 39, ·46, ·31, ·24, and differs from *U. derancei* only in being more boldly ribbed and in retaining the umbilical tubercle to a larger diameter.

The form here described differs from *U. subornata* sp. nov. chiefly in its almost obsolete constrictions and its simplified suture-line, which lacks the sharp decline of the auxiliaries towards the umbilicus ; the style of ornamentation is also more reminiscent of *Cleoniceras quercifolium* (d'Orbigny).

Of special importance is the relationship between *U. derancei* and *Beudanticeras subparandieri* Spath, a variable species of the *cristatum* subzone (Bed VIII). Unfortunately, the inner whorls of the holotype of this species are corroded, but there are available a number o topotype specimens (e.g. G.S.M. 83104 and S.M. B 30797) which may be assumed with a reasonable degree of confidence to be conspecific with the holotype. In these specimens the feeble primary ribs reach right down to the rim of the umbilicus but do not become tuberculated, even on the inner whorls. *U. derancei* is readily distinguished from this form by its much coarser, tuberculate, ornamentation, although the two species are very similar in general habitus and are almost

identical in sutural characters. Indeed, among the variants of *B. subparandieri* in the *cristatum* subzone is an extreme form which may be regarded as transitional between the two species (Pl. XIX, figs. *4a–b*). The ribbing of this form is a good deal more pronounced than that of the typical *B. subparandieri* and the primary ribs are feebly nodate in the umbilical region ; it thus stands about halfway between *Uhligella* and *Beudanticeras*. The coarse specimen of *B. subparandieri* (B.M. 796*a*) mentioned by Spath (1923, p. 62), since decomposed and thrown away, was probably a similar passage-form.

Now, *B. subparandieri* may be linked just as convincingly with the smooth *B. beudanti* (Brongniart), which ranges from the condensed Bed VIII to Bed XI at Folkestone, so that having regard to the stratigraphical evidence it does not appear unreasonable to suggest that this morphological series from *Uhligella derancei* to *Beudanticeras beudanti* denotes actual biological continuity, the lineage showing progressive reduction in ornamentation and whorl-thickness, correlated with increased complexity of the suture-line. It is opportune here to point out that the highly ornate *U. balmensis* occurs already in the *nodosocostatum* zone (Breistoffer, 1947, p. 7) and therefore precedes the closely connected but morphologically simplified *U. rebouli*, which in turn leads on to *Beudanticeras*. When reviewing the generic succession in the Desmoceratidae Whitehouse (1926, p. 218) also offers the opinion that *Uhligella* has given rise to species of *Beudanticeras*. Spath, however, inclines to the belief that in this genus, as in all the Desmoceratidae, smoothness is an original feature (Spath, 1923, pp. 31–2).

Uhligella derancei var. *erugata* nov.

This varietal name, which it may be desirable to employ in a specific sense on discovery of more complete material, is applied to a form which differs from the typical *U. derancei* in the following respects : the whorl-section is more compressed, the costation less bold, with the primary ribs delicately emphasized rather than tuberculate around the umbilical region ; the venter is almost completely smooth already at 15 mm. diameter. A specimen collected by L. F. Spath (G.S.M. 83100), figured Plate XIX, fig. *3a–b*, may be taken as the type of the variety. There are two other specimens (B.M. C 32865 and C 32869),[1] and all three are preserved as internal moulds in pyrites

[1] Specimens C 32868 and C 32869 in the British Museum are accompanied by a note in Dr. Spath's handwriting, which I quote with the author's permission : "Probably a new species of *Beudanticeras*, resembling *Cleoniceras devisense*, apparently from Bed II, but never found by *myself* and therefore not described. A '*pre-subparandieri*' form." In the Gault Monograph (1942, p. 693) specimen C 32869 is described as a "*devisensis*-like undescribed species of *Cleoniceras*". The "slightly more inflated form" (B.M. C 32867) referred to in connection with this specimen is a nucleus of the typical *Uhligella derancei*.

and almost certainly came from Bed II, as the label " Black Bed " on one of them would indicate. The two larger specimens have dimensions as follows :—

	G.S.M. 83100.	*B.M.* *C* 32865.
Diameter in mm.	25	33
Whorl-height (in % of diameter) .	48	47
Whorl-thickness (in % of diameter) .	32	30
Umbilicus (in % of diameter) . .	25	25

Two small examples (B.M. C 32866 and C 32868) combine the lateral aspect of the typical form with the whorl-thickness and smooth ventral area of the var. *erugata*. This variety is of especial interest because it connects *Uhligella* with such forms as " *Desmoceras* " *bicurvatoides* Sinzow (1909, plate ii, figs. 7–18) and its ally *Cleoniceras ? devisense* Spath (1923, p. 94). These two species represent a group which, although too imperfectly known to be separated generically, appears to have been derived from *Uhligella* independently of *Cleoniceras*, which it replaces in time. The var. *erugata* is distinguished from this group only by the persistence of vestigial constrictions beyond the ephebic stage and the consequent slight irregularities in the ribbing.

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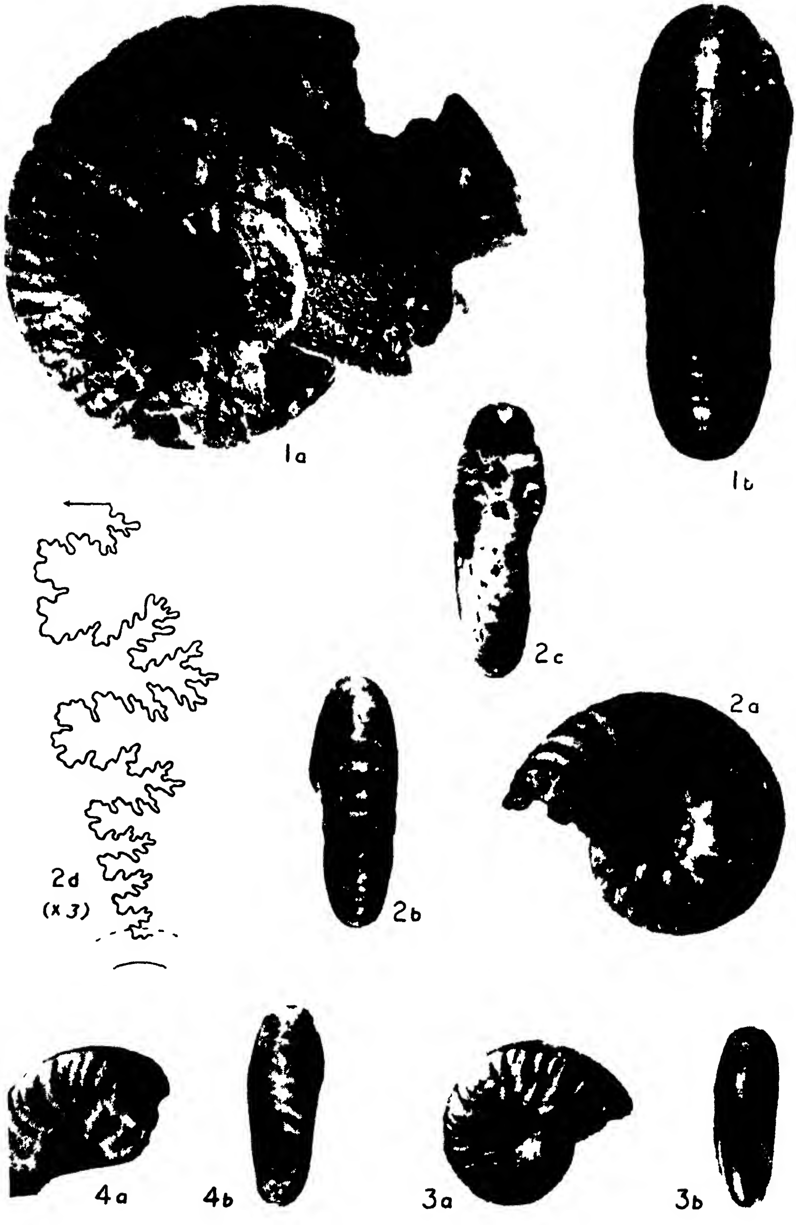

[J. Rhodes photo.

UHLIGELLA FROM MIDDLE ALBIAN OF FOLKESTONE.

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EXPLANATION OF PLATE

All Figs. natural size, except Fig. 2*d*

FIG. 1.—*Uhligella subornata* sp. nov. Holotype (R. Casey Collection, G.S.M. 70442). Side view (*a*) and peripheral view (*b*). Folkestone Beds (Mammillatum bed), Middle Albian, *mammillatum* zone, *monile* subzone. Foreshore reefs just east of Copt Point, Folkestone.

FIG. 2.—*Uhligella derancei* sp. nov. Holotype (R. Casey Collection, G.S.M. 82908). Side view (*a*), peripheral view (*b*), and apertural view (*c*), with external suture-line (*d*) enlarged × 3. Lower Gault, Bed II (*dentatus* zone, *intermedius* subzone). Foreshore reefs, East Wear Bay, Folkestone.

FIG. 3.—*Uhligella derancei* sp. nov., var. *erugata* nov. Type of variety (L. F. Spath Collection, G.S.M. 83100). Side view (*a*) and peripheral view (*b*). Gault, Folkestone. Found loose, but presumably from Bed II.

FIG. 4.—*Uhligella* sp. ? (L. F. Spath Collection, G.S.M. 83101). Side view (*a*) and peripheral view (*b*) of part of the inner whorls of a large fragmentary specimen transitional between *Uhligella derancei* sp. nov. and *Beudanticeras subparandieri* Spath. Lower Gault, Bed VIII (*lautus* zone, *cristatum* subzone). Folkestone.

Hilt's Law and the Volatile Contents of Coal Seams

By O. T. Jones

(*Concluded from p. 312*)

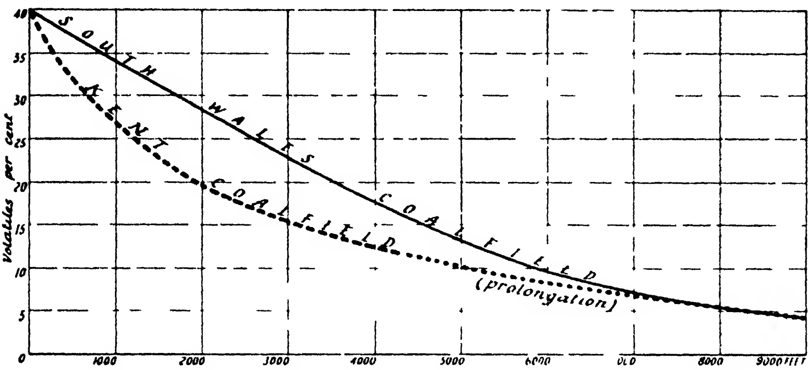
General Relations between Volatile Percentages and Depth

Arbitrary relations between volatile percentage and depth of the seams can be established readily for both the South Wales and Kent coalfields by means of the Hilt rates: this is perhaps most clearly indicated by the South Wales sequences, which are considered first. If we take as a horizontal datum plane a seam which contains 40 per cent of volatiles we can calculate from the Hilt rate the depth for any given sequence at which the Nine-Foot seam would lie below that datum. Thus, at New Bridge the recorded volatile content of the Nine-Foot seam is 28; a least squares solution gives 26·7; adopting a value of 27 and a Hilt rate of 5·32, that seam would be 2,440 feet below the datum. At Treherbert the recorded volatile is 11, while a least squares solution gives 11·5; the depth of the Nine-Foot seam below the datum would thus be 5,400 feet. It is clear, therefore, that if the 40 per cent seam were regarded as a horizontal plane, depression was at one time more rapid in the west than in the east. It is known that a rapid increase in the thickness of the measures below the Pennant Sandstone takes place westward, but the difference of 3,000 feet indicated above is much more than occurred by differential warping during the formation of the lower measures among which the Nine-Foot seam lies. The tendency which is evident, however, in these lower measures must have continued into much later Coal Measure times, in which case a 40 per cent datum was itself warped down.

It is possible by thus making use of the Hilt rates to find an arbitrary volatiles/depth relation on a line such as AE along the whole length of the coalfield between New Bridge and the Gwendraeth Valley. This is shown in the section, Text-fig. 3. From the general uniformity of the rates not only along the above line but for at least 6 miles on each side of it, one may provisionally associate with each isovol in that area a particular depth of the Nine-Foot seam measured down from the 40 per cent seam as a datum. From the section and the isovol map it would thus be possible to construct an isobath map showing the depth at every point below the datum.

Even a 40 per cent seam started life, however, as vegetation in a peat swamp; what the volatile content of such an organic layer would be is guesswork but it is not improbable that it was 80 to 90 per cent at least. If for purposes of argument we assume that the Hilt rates found for the eastern sequences hold for the interval between the 40 per cent seam and the surface, we find (using the average Hilt rate 5·37) that the cover on the 40 per cent seam would be about 7,450 feet if the peat

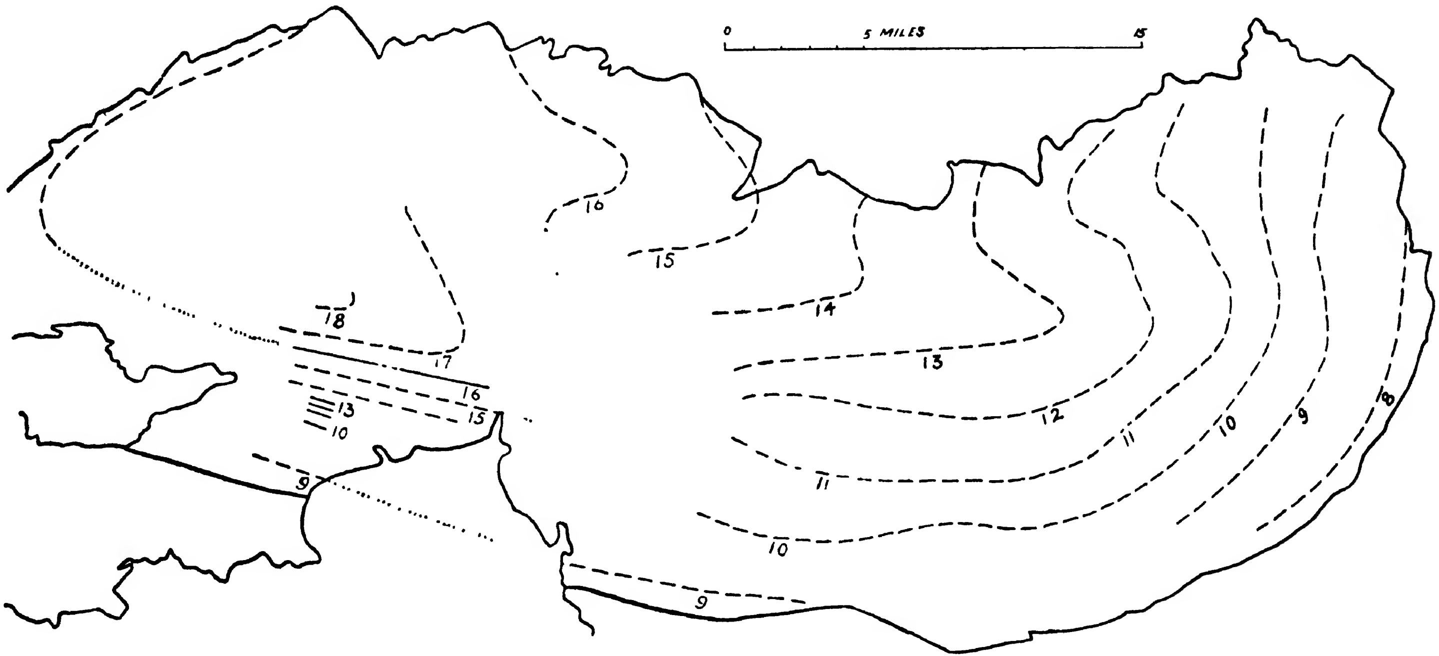
had a volatile percentage of 80 and about 9,300 feet if its content was 90 per cent. The only check that I know of on such figures is that given by a borehole at Notown, Greymouth, New Zealand, which is referred to by H. W. Wellman, 1948. This borehole " passed without apparent metamorphic break from peat in the surface beds through sub-bituminous coal at 3,000 feet to bottom in high volatile bituminous coal



TEXT-FIG. 3.—Relation between volatile contents of coal seams and depth below a given datum in (*a*) South Wales along an E.–W. line and (*b*) the Kent Coalfield on a N.W.–S.E. line.

at 7,000 feet ". In a letter Wellman states that the exact depth to the bottom seam was 6,893 feet and from analyses which he kindly included, the volatile content of the seam on an ash-free dried basis was exactly 50 per cent. If we adopt figures of 80 or 90 as possible volatile contents of peat, the average rate between this seam and the surface is 4·35 per cent per 1,000 feet or 5·8 per cent respectively. Extrapolating these rates would suggest that the cover on a 40 per cent seam under similar conditions would be 8,600 or 9,200 feet. There is closer agreement between these figures and the above estimates for South Wales than we have any right to expect, but it suggests that the estimate of the cover on a 40 per cent seam in South Wales is not wildly wrong.

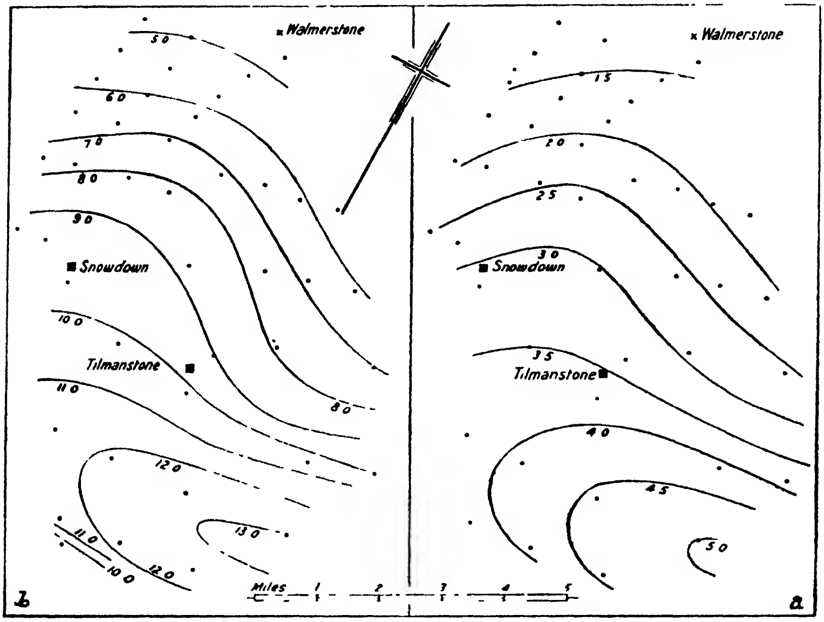
If, therefore, we added a round figure of 8,500 feet to the depth of the Nine-Foot seam below the 40 per cent datum, a 5 per cent anthracite would have been covered by nearly 17,000 feet of sediments. It is improbable, however, that the cover on a 40 per cent seam would have been uniform over the coalfield. Text-fig. 4 shows an isobath map giving the approximate depths to which the Nine-Foot seam was probably buried below the surface at the end of the Carboniferous. By reason of subsequent compaction the original depth may have been 2,000–3,000 feet at least greater than the above figure. In the western part of the field about 4,000 feet has been added



TEXT-FIG. 4.—Isobath map showing probable maximum depth of cover on the Nine-Foot seam, South Wales Coalfield. Figures indicate depth in thousands of feet.

to the cover on the Graigola seam to give the probable cover on the Nine-Foot seam.

By combining the Hilt rates with the isovols the same method can be used in the Kent coalfield to determine either the depth of some horizon below a 40 per cent datum or approximately the depth of



TEXT-FIG. 5.—*a* Approximate isobaths of Millyard seam at close of Coal Measures deposition.
b Approximate isobaths of Millyard seam below an assumed datum plane of a seam containing 40 per cent of volatiles.

that horizon below the surface at the end of the Carboniferous (see Text-fig 3 for comparison with the relation in South Wales).

The horizon of the Millyard seam which is about 800 feet above the base of the coal measures is chosen. Taking the intersection of isovol 25 with the Hilt rate 10, the difference between the volatiles of the datum at 40 and the Millyard seam at that point is 15, which divided by 10 per thousand gives a depth of 1,500 feet. By using in this way the remaining intersections the contoured isobath map Text-fig. 5*a* is obtained. Since the depth below the datum at any point on a given isovol varies inversely as the Hilt rate it is obvious that the trends of the isobaths must bear a resemblance to those of the lines of equal Hilt rates. This map brings out clearly the original trough-like form which the basin assumed during the deposition of the measures. An even more interesting result in comparison with South Wales is obtained if the Hilt rates are used to calculate the possible total cover on the Millyard seam. The result is shown in Text-fig. 5*b* where the depths

at the intersections of Hilt rates and isovols are in thousands of feet. This isobath map portrays a deep geosyncline with a sharply defined east and west axis and so far as the indications go a steeper slope on the south than on the north. At Oxney near the axis where the Millyard seam might be expected to have a volatile content just below 15 per cent, if the effect of cover is the same as in South Wales it would take an additional cover of 3,500 feet to produce a 5 per cent anthracite seam giving a total cover at that point of nearly 18,000 feet. If, as in South Wales, we add a cover of 8,500 feet on the 40 per cent seam the result at Oxney would be a depth of burial of about 14,000 feet.

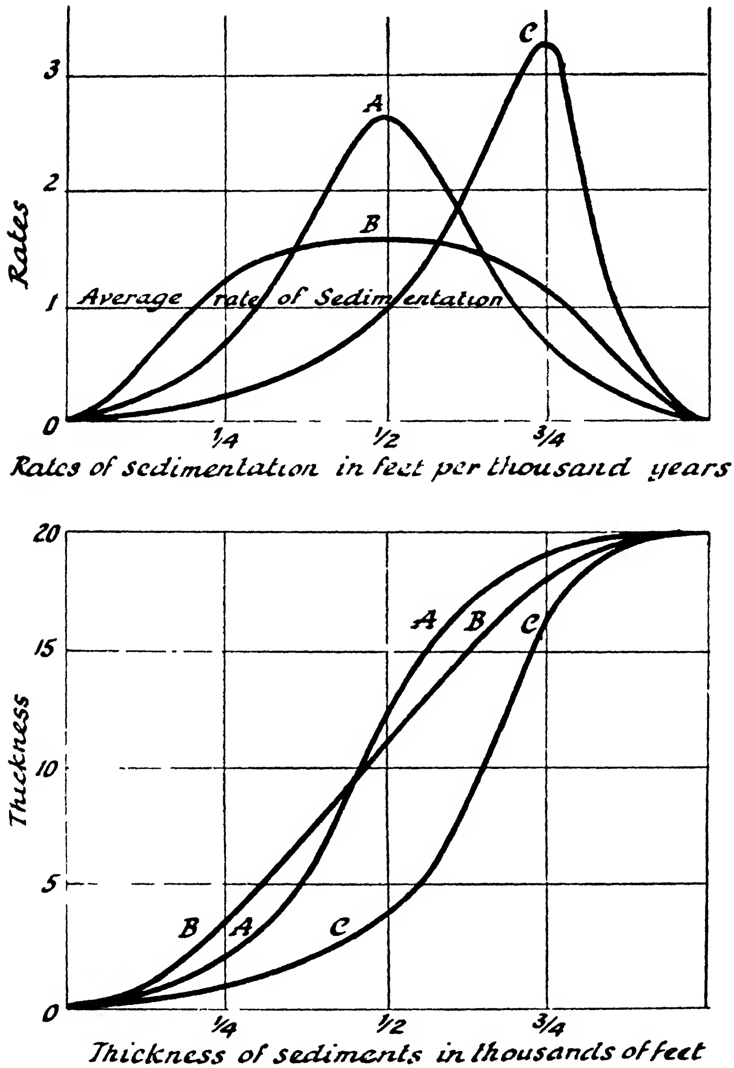
It is interesting to compare these deductions with the conclusions drawn by H. W. Wellman, 1948, from his study of the metamorphic gradients in this field which was based on the data published by Dines. He noted that the metamorphic gradient changed considerably from north-west to south-east and concluded that at the centre of the syncline the original depth of the base of the coal measures was about 14,000 feet. It may be added that if a coal seam occurred at the base its volatile content there would be about 10 per cent, which suggests that the cover on a 5 per cent anthracite seam in the Kent coalfield might be expected to be about 17,500 feet. Wellman estimated that at the north-east (? north-west) margin of the field the cover would be only about 9,000 feet ; there is reason to believe that even this latter figure is an over-estimate. If Wellman's metamorphic gradient is doubled it gives approximately the depth of the base of the coal measures at those points. He concluded (p. 508) also that " the progressive rise of the isogeotherms through the beds and the progressive increase in weight of overburden caused each seam to be progressively metamorphosed. Coal metamorphism was completed when the isogeotherms reached their highest level ". It will be observed that Wellman attributed the metamorphism to a rise of temperature and to an increasing weight of overburden.

Changes Induced in Coal by Progressive Burial

It is of interest to inquire next how increasing temperature and pressure may have controlled the changes which took place in layers of vegetation between their accumulation at the surface and their subsequent burial to varying depths. If we consider a series of coal seams, S_1, S_2, etc., which lie at a depth of several thousand feet below the surface, let V_1, V_2, etc., represent the volatile contents of those seams at the present time and Y_1, Y_2, etc., their depths below the original surface. Hilt's law expresses the relation

$$h = -\frac{V_1 - V_2}{Y_1 - Y_2}$$

the negative sign indicating that the volatiles decrease in depth. The depth Y_1 was attained by depression from the original surface on



TEXT-FIG. 6.—Diagrammatic representation of varying rates of sedimentation in a Coal Measures geosyncline, and the cumulative thickness resulting from these rates.

which S_1 accumulated followed by the re-establishment of that surface level by sedimentation; the difference $Y_1 - Y_2$ between the two seams S_1 and S_2 corresponds to an interval of time multiplied

by the rate of depression or what is the same thing the rate of sedimentation which maintained the level of the surface prior to and during the formation of S_2. The rate of sedimentation varied from one part to another of a given area of deposition which subsequently became a coalfield. As most of these coalfields were geosynclines the depression and consequent sedimentation was greater in the axial than in the marginal region. If, however, we select some particular place, say near the axial region, and consider its depression throughout the history of the basin, sedimentation may have begun at a zero rate, then increased to a maximum, finally falling off to zero at the end of the Carboniferous period when depression began to give way to uplift of the area. While this assumption that sedimentation began at a very slow rate probably applies to the geosyncline as a whole it is possibly not strictly true for the Coal Measures which are the last phase in the formation of the Carboniferous geosyncline and therefore inherited a particular rate of sedimentation from the immediately preceding formation, the Millstone Grit. Where, however, as in the Kent coalfield the Coal Measures rest with a non-sequence upon Carboniferous limestone or older beds the assumption is probably true. A, B, and C, Text-fig. 6, represent different ways in which the rates of sedimentation might have varied within the full period of accumulation of the Coal Measures. In A the maximum rate was attained towards the middle of the period and the rates before and after the maximum were similar. In B the rate remained during half the life of the Coal Measures near the maximum, while in C the culminating point was reached late in the history of the basin and fell off rapidly to the end. The corresponding increase in thickness are shown in Text-fig. 6. The total thickness represented by the areas of the figures is the same for A, B, and C. Since in many geosynclines uplift began on the border of a basin while deposition was still continuing within the basin the products of erosion transferred from the rising region to the still sinking basin accelerated the process of depression and raised the rate of sedimentation ; the curve C may represent that type of behaviour.

According to the depth of burial theory the organic matter of the peaty swamp began to decay as soon as the plants died and it is generally agreed that the process was actively promoted by micro-organisms ; White, 1908, gives a good account of this stage of coal formation. As the organic layer became buried further changes occurred under anaerobic conditions. Decay resulted in a loss of volatile matter ; if a seam stayed for a long time near the surface oxidation may also have caused loss of volatiles and it is known that different samples of surface peat exhibit a considerable range of volatile content (see Raistrick and Marshall, 1939, p. 224). The effect of micro-organisms ceased when the temperature became too high for their survival

but it is not impossible that lignites may have formed at a depth of some thousands of feet mainly by bacterial action. At greater depths further changes must be attributed to the higher temperatures at those depths; in that case chemical activity controlled by the physical conditions must have been the chief cause of loss of volatiles. The seams S_1, etc., reached at some time equilibrium with their environment so that their volatile contents became, as it were, frozen and little if any change has taken place subsequently, however long a period of time may have elapsed. The difference between the volatiles V_1 and V_2 must therefore be attributed to the difference in depth between Y_1 and Y_2 and the Hilt rate is a measure of this effect.

The differences of opinion between proponents of the two main theories of the devolatilization of coal turn largely on the period at which the volatiles became frozen. Advocates of the depth of burial theory claim that the devolatilization of British coals was almost if not quite completed before the post-Carboniferous movements became active, but those who believe in tectonic effects maintain that this did not occur until the coalfields were subjected to earth movements leading to folding and faulting. It is doubtful if any advocate of the tectonic theory would hold that no change occurred in the seams during their burial so that the point at issue between rival theories is the period and manner of "finishing off" of the seams.

The process of change from peat to anthracite appears to be so continuous that no one can point convincingly to any composition or volatile content which divides off the effects of one agent or manner of decomposition from those of another.

It is assumed therefore that when a seam such as S_1 arrived at its final depth, it had already been divested of a large fraction of its initial volatile content. Different coal seams of a given volatile content are so nearly of the same composition that they fall within a very narrow band of composition or volatile contents (Hickling, 1932, and Trotter, 1948). One can therefore resort to the fiction that a number of different seams now found at increasing depths may be made to represent the history of one particular seam at different stages of its descent below the surface where it originated in a swamp. It is not thereby assumed that while occupying the positions Y_1, Y_2, etc., this seam had the final volatile contents V_1, V_2, etc.

The volatile content as determined on a sample of coal in a laboratory under standard conditions is not the whole of the potential volatiles in that sample, for if it were heated for a longer period or for the same period at a higher temperature than the standard temperature of 925° C., more volatile matter would be given off. To expel the whole of the volatiles, leaving a residue of carbon only, would probably require the heat of an electric arc. Thus the volatiles driven off at

925° represent that fraction of the total volatiles which is *expendable* under the conditions of the experiment.

When the seam S_1 reached the level Y_1 it had already lost a large portion of its initial volatile content, and if it stayed in that environment for a long time it would ultimately reach the volatile content V_1 or near thereto, at which it was thereafter frozen. If, however, after that time it was depressed to Y_2 and remained there permanently its volatile content would become V_2. In changing from the depth Y_1 to the depth Y_2, the seam at Y_1 had an expendable volatile content v_1 which, if the descent took a very long time, would approach V_1–V_2 as a limit ; though, in general, v_1 might be somewhat less than V_1–V_2. Let us then assume for simplicity that the seam is depressed suddenly from Y_1 to Y_2, so that it arrives at Y_2 with its expendable volatile content v_1 intact. At the new level Y_2 reaction sets in under the changed environmental conditions, leading to a using up of part or the whole of this expendable volatile matter.

The rate at which the volatile content changed with time must be presumed to have depended on the temperature and probably also on the pressure and both of these are functions of the depth ; it is also probable that in accordance with the law of mass action the rate was proportional to the amount of volatile matter remaining to be expended at a given time. These conditions lead to an exponential relation such that

$$v = v_1 \, \epsilon^{-\lambda t}$$

where λ represents the combined effect of the chemical and physical factors and may be regarded as a sort of decay factor. If the seam remained at this level Y_2 for a time short of infinity, it would pass through various stages such as that at each stage some fraction $\frac{1}{m}$ of v_1 remained unspent. If, for example, m is taken as 2 this corresponds to what is called the half-life of v_1 and the time required to reach it is the " half-life period " which is given by

$$T = \frac{\log_\epsilon 2}{\lambda} \text{ or } \frac{\cdot 69}{\lambda}$$

If, on the other hand, m were taken as 10, T would be $\frac{\log_\epsilon 10}{\lambda} = \frac{2 \cdot 3}{\lambda}$ or just over three times as long. The change of depth $Y_1 - Y_2$ on this view is, however, the amount by which the seam was depressed by sedimentation at the surface while these reactions were going on. If instead of being depressed suddenly the seam descended gradually from Y_1 to Y_2 the reactions discussed above would probably not be much

altered, but the change of depth $Y_1 - Y_2$ would represent the amount of sediment which was laid down at the surface in the time required for the expendable volatile content of the seam to be reduced to $\frac{1}{m}$ of its initial amount v_1. If we call the average rate of sedimentation S, then $Y_1 - Y_2 = ST'$ and T' is proportional to $\frac{\log_\epsilon m}{\lambda}$. The Hilt rate is thus seen to be proportional to $\frac{\lambda}{S}$. If we consider stages such that the changes of volatile content from one depth to another were the same, the Hilt rate would measure the relative effect, on the one hand, of the chemical and physical factors at the level of the seam and, on the other, the rate of sedimentation at the surface at that stage. Thus, if we compare two places, one near the margin of the geosyncline and the other near the axis, and suppose that S near the margin is one-third of its value near the axis then for equal differences of volatile percentages and at the same depths below the surface the Hilt rate in the one case would be three times that in the other. We have some such relation if we compare the north-west part of the Kent Coalfield, as at Stodmarsh, with the axial region, as at Oxney.

It would appear therefore that the Hilt rate may be controlled largely by the rate at which the seams were depressed by sedimentation at the surface during successive stages of devolatilization and *not by the rate of sedimentation which prevailed at the time when the seams were laid down.* Since the rate of depression may have varied from time to time and from place to place the Hilt rate may thus reflect the geological history of sedimentation in the coalfield.

This interpretation of the Hilt rate as a reflection of the varying history of sedimentation within a given coalfield both in space and in time accounts readily for the changes of rate observed in the Kent Coalfield. Towards the north-west margin sedimentation was slow and the Hilt rates high whereas near the axis the reverse was true. It is not impossible that the difference between the Hilt rates at Stodmarsh and Oxney are due solely to varying rates of sedimentation and that the chemical-physical factors remained almost unchanged throughout a depth of burial of 10,000 feet. It is unlikely, however, that there was such a difference in sedimentation between points only 10 miles apart, and in such a case the chemical-physical factors must have diminished as the depth of burial increased. In the South Wales Coalfield, however, we have to consider this interpretation in relation to two regions of widely different behaviour. In the eastern half of the coalfield the Hilt rates are uniform in spite of the fact that the sedimentation increased

from east to west. Thus if h varies as $\frac{\lambda}{S}$ then since it is clear that S increased from east to west, it would appear that λ must have diminished in that direction in order to preserve a constant ratio. This is at first sight contrary to what might have been expected, since the greater depth of burial and the greater temperature to which the seam must have been exposed in the western part of the region might have been expected to increase the chemical activity. The case is paralleled, however, as we have seen, in the Kent Coalfield, where the decay factor was probably greater under the shallow cover than under the deep cover.

In the three western sequences in South Wales, however, the Hilt rate drops so markedly, attaining at the Gwendraeth Valley a rate less than one-fifth the rate at Treherbert, that this explanation is not fully satisfactory. It may be noted that the effect of diminished volatile content, or the " law of diminishing returns ", has already been taken into account in deriving the exponential formula since that is based on the assumption that the loss of volatiles at any time is proportional to the total volatiles expendable at that time. It can hardly be assumed that the rate of sedimentation at the Gwendraeth Valley increased to anything like five times the rate at Treherbert ; the diminution in the Hilt rate must therefore be attributed to a marked decrease in the rate of the combined chemical and physical effects expressed by the decay factor λ. The conclusion that some diminution in this factor occurred with increasing depth of cover has already been reached in considering the six eastern sequences and is supported by the variation of Hilt rates in the Kent Coalfield. A further diminution in the factor between Treherbert and the Gwendraeth Valley is therefore to be expected as the depth of burial increased. Whether, however, the decrease to less than one-fifth can be accounted for by that explanation is very doubtful in view of the relative suddenness of onset of the change in Hilt rates between Treherbert (5·26) and Resolven (3·31) in a distance of just over 6 miles. It is, in fact, unlikely that the rate of sedimentation at Gwendraeth Valley was ever twice as great as at Treherbert.

Where the marked change sets in the volatile percentages are below 16 and the lower seams even at Resolven are of anthracite rank. Since the final stages of devolatilization result in a progressive loss of hydrogen, whereas the earlier stages are indicated mainly by a loss of oxygen, it is possible that the considerably lowered rate of chemical-physical activity near or within the anthracite range is due to a *change in the character of the reactions* whereby a given temperature has relatively less effect in reducing the volatile content than at the higher levels.

THE FACTORS CONTROLLED BY DEPTH OF BURIAL

Temperature.—The reactions that take place in a coal seam at depths great enough to allow us to discount the effect of micro-organisms are presumably some function of temperature which may be assumed to increase in more than linear ratio with rise of temperature. As an illustration of a function exhibiting this behaviour we may take the vapour pressure of water, which is ·12 bars at 50° C., 1·01 at 100°, 15·55 at 200°, and 46·94 at 260° C. (*Handbook of Physical Constants*, p. 210) ; one bar is about one normal atmosphere. It is not implied that the actual function of temperature which governs the coal reactions behaved like the pressure of water vapour though it is not unlikely that this along with the pressure of other vapours generated by the decomposition of the coal plays a part. The great difference in activity caused by a rise of temperature of a few degrees above the boiling point of water brought about by a pressure of a few atmospheres is seen in an ordinary pressure-cooker.

Pressure.—It has been commonly assumed that the high pressure which prevails at a depth in sediments must have caused a loss of volatile matter in coal seams. The effect is apparently regarded as comparable with the squeezing out of water from a muddy sediment under load and, in so far as it is known that coal seams do lose moisture with increasing rank and depth of burial, pressure probably plays the same role in a coal-seam as in an ordinary fine-grained sediment. The reactions between the chemical constituents of a coal seam which lead to a loss of carbon, oxygen, and hydrogen in certain proportions are, however, chemical reactions, and without knowing precisely what they are it is probably safe to assume that they result in an increase in the aggregate volume of the coal and its products of decomposition. If this is a correct assumption, then pressure would undoubtedly retard the reactions by making it difficult to get rid of the volatile products. If the environment was such that none of these products could escape the reaction would be totally inhibited.

Mr. Maurice Hill informs me that a high explosive such as dynamite, which like a coal contains the oxygen necessary for its decomposition, will not explode below quite a moderate depth of water on account of the inhibiting effect of pressure.

Pressure may therefore inhibit the reaction altogether, in which case burial below a certain depth cannot diminish the volatile content of a seam below a given amount or it may greatly retard the reaction by preventing the easy escape of volatiles. In view of the progressive change in the volatile contents of coal seams down to very low values total prohibition is unlikely. The other role would diminish the decay factor λ and thus lead to a low Hilt rate at a great depth, whereas if the conditions are such that the products at any level can escape freely,

the decay factor and consequently the Hilt rates are high. Pressure may exert such a retarding effect through a reduction of the minute channels which communicate from one pore to another in a fine-grained sediment. Professor Illing, 1944, remarked that "there was considerable evidence that compaction of sediments is in some cases brought to a stage of temporary equilibrium by the inability of the fluids to force an exit".

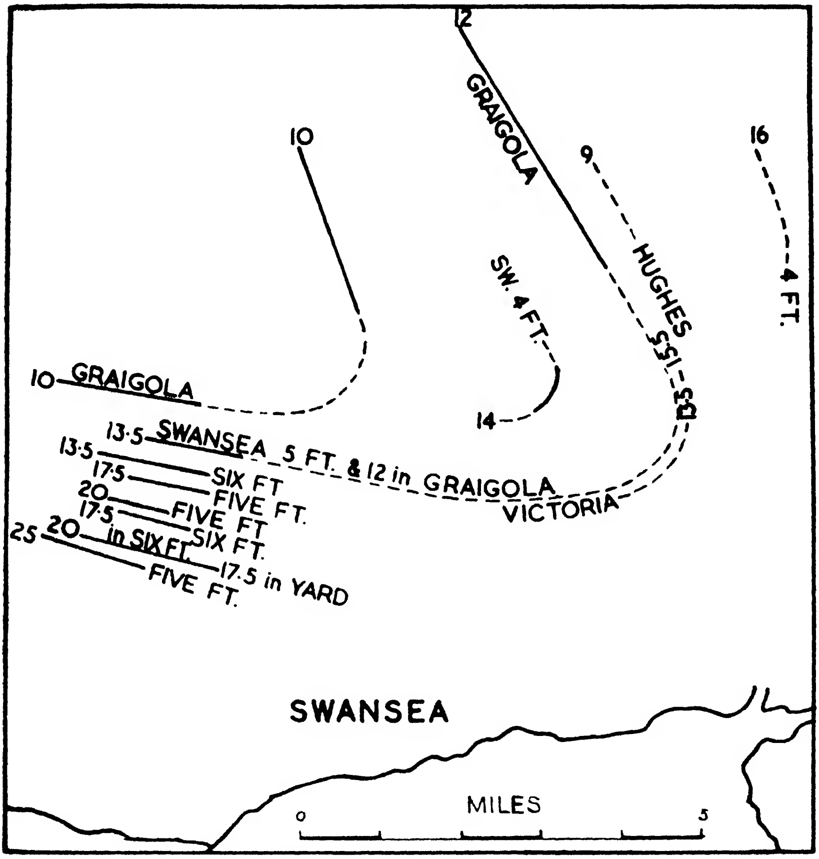
If, therefore, we assume that the reaction is controlled by some function such as porosity which decreases in more than linear ratio with depth, its product with a temperature function which increased in more than linear ratio with depth might be almost constant through a great range of depth until the effect of one or the other became predominant. This is illustrated in the following Table, in which it has been assumed for convenience that the temperature increases at the constant rate of 1° C. per 100 feet in depth, starting from a surface temperature of 20° C. The porosity has been calculated in accordance with Athy's relation between porosity and density in muddy sediments.

Depth, Feet	Pressure of Water Vapour in Bars	Calculated Porosity %	Product
2,000	·074	25	1·85
4,000	·199	9·9	1·97
6,000	·312	6·2	1·95
8,000	1·013	1·5	1·58
10,000	1·985	·6	1·21
12,000	3·614	·24	·87
18,000	15·552	·015	·23

The product of these two functions varies only as 1 to 8 over a range of depth of 16,000 feet and between 2,000 and 8,000 feet it varies only about 20 per cent. It is believed, therefore, that the combined effects of temperature and pressure functions which act in opposite directions, may largely explain the varying rates of devolatilization of coal, which in turn are reflected in the variation of Hilt rates from one part to another of a coalfield or from one coalfield to another. It is also necessary to take into account the rate of depression of the area which controls the rate of sedimentation in that area. It may be remarked, however, that whatever may be the exact mode of metamorphism of coal resulting from depth of burial, it certainly cannot be described as load metamorphism since it would be much more effective if, other conditions being present, the load were absent. With these simple assumptions it is possible to explain all the examples of greatly varying rates of devolatilization with depth which have been reported from British coalfields.

Brief reference may be made to two other regions in illustration of some of the difficulties encountered in interpreting varying Hilt rates.

The first region lies to the north-west of Swansea where three seams have been extensively worked ; these are in descending order : the Swansea Four-Foot, the Swansea Five-Foot, and the Swansea Six-Foot, widely known as the Graigola seam. The Coal Survey isovol



TEXT-FIG. 7.—Isovol map of coal seams north-west of Swansea. (Based on Coal Survey Isovol map.)

map shows certain isovols for these seams and some information regarding other near-by seams in the Pennant Sandstones (Text-fig. 7).

On the south side of a N.W.–S.E. axis of minimum volatile contents which, by the way, has nothing to do with the axis of a syncline which ranges in a wholly different direction a few miles to the north, the isovols in the Five-Foot and the Six-Foot seams pursue remarkably parallel courses, but the volatile percentages change very rapidly across their trend, while the average vertical distance between the two seams remains about 410 feet.

From the information available we find that at isovol 12 in the Six-Foot, the Hilt rate between the Five-Foot and the Six-Foot is 3 per

cent per 1,000, but farther south at isovol 25 on the Five-Foot the rate is 11·8 per cent per 1,000. The distance in which the Hilt rate is reduced to one-quarter is only just over a mile. It is obviously too hazardous to extrapolate these values to the surface as the depth range is too short. These relations along this portion of the south side of the coalfield recall, however, those in the Kent Coalfield between the axis and Bere Farm to the south. There seems to be no doubt that at one period in the history of the coalfield the thickness of the measures must have increased at a very rapid rate from the Gower peninsula where the rate of sedimentation was low towards the centre of the coalfield where as we have seen, the rate was probably high. The south-western part of the coalfield is almost certainly another example of the rule that where the measures were thin the Hilt rates were high and where they were thick the Hilt rates were low.

The other region is that of the Pie Rough bore in North Staffordshire, the coals of which were so carefully and systematically investigated by Millott, 1946. Within a depth of 4,210 feet from the surface samples from sixty-two horizons were analysed, both proximate and ultimate analyses being recorded. If one takes account of every layer separated by a foot to 3 feet only from the adjoining layer and gives equal weight to each, the result is unduly to favour a thick seam or what is almost the same thing, a series of several thin seams within a limited depth of strata. I have, therefore, averaged these analyses either into single horizons or assemblages of horizons separated by small depth intervals. The difference in treatment is not great but the grouping method gives a fairer representation of the changes of volatile content with depth.

It is quite evident as Millott reported that a uniform rate of change cannot be applied throughout the sequence. I therefore divided the vertical column which contains coal seams into three approximately equal depths, and calculated by least squares the Hilt rates for each depth range. Millott used two different methods of determining the volatile percentages ; these differ slightly but systematically from one another, the difference increasing on the whole with the volatile contents of the seams. The two methods cannot therefore lead to the same Hilt rates, which have been determined for each method separately.

The results are summarized in the following Table :—

	No. of Groups	Gas Method	V_0	Electric Furnace	V_0	Depth Range	Diff.
Upper Series, Nos. 1–21 .	12	3·23	46	5·4	50	728–1873	1145
Middle Series, Nos. 22–33 .	8	4·59	50	5·07	52	1873–3038	1165
Lower Series, Nos. 33–62 .	17	7·16	61	9·0	66	3038–4213	1173

As in other cases it is possible to explain these varying rates by a combination of the three factors, one due to temperature, the second an inhibitant—the pressure, and the third independent of both which is the rate of sedimentation. Thus, if we suppose that the chemical-physical factors remained unchanged the figures would suggest an acceleration of sedimentation at the surface, while the seams were near the finishing-off stage.

From the various examples which have been discussed it is obvious that *there is no simple mathematical law of devolatilization with depth which is applicable to any coalfield as a whole or even to different parts of one coalfield.* An arbitrary relationship can, however, be found for any coalfield, provided the Hilt rates and the volatile contents are known. The more numerous and the better distributed these are, the more that can be learnt regarding the geological history of a coalfield, the final depth to which any given coal seam was once buried below the surface and, knowing its present altitude, the amount by which that seam has been uplifted by subsequent movements.

In the South Wales Coalfield the measures thicken rapidly from east to west and the officers of the Geological Survey estimated that in the south-western part of the coalfield the measures were about 7,000 feet, which, even so, is less than half the final thickness of cover on the Nine-Foot seam suggested by the depth-of-burial theory. Consideration of a wider area suggests, however, that the Upper Carboniferous sedimentary column is far from complete in the South Wales Coalfield.

While normal sediments were deposited in South Wales in the zone of *Anthraconauta phillipsi* and *A. tenuis*, we find that in North Staffordshire the zone of *A. phillipsi* includes the red measures of the Etruria marl group about 1,000 feet thick. In the succeeding Newcastle group there was a partial return to the normal conditions, but the *A. tenuis* zone consists of the Keele group of red marls which may attain a thickness of 700 feet. The Keele beds are followed by the calcareous conglomerates and breccias of the Enville group which in Warwickshire attain a maximum thickness of 3,500 feet. Thus at their maximum these largely abnormal sediments amount to nearly 6,000 feet and suggest the types of deposits which may have occurred generally in the final stages of deposition of the Coal Measures before uplift put an end to the process. By comparison with the development of the Coal Measures on the Continent even the highest of these measures probably does not mark the upper limit of the Carboniferous period.

It is not unreasonable to suppose that the closing stages of sedimentation in the South Wales Coalfield were marked by somewhat similar changes and types of sediment as are recorded in the North Staffordshire and other Midland coalfields, and that a considerable thickness

of "continental" deposits was present at one time. There is, in fact, every reason to assume that the thickness of such deposits may have been substantially greater in South Wales than in the Midland region, by reason of the situation of this coal basin on the northern flank of the Armorican geosyncline. It is probable, however, that the deepest part of this geosyncline lay farther south in Devon and Cornwall, where the aggregate thickness of sedimentary rocks may well have considerably exceeded that in South Wales. As in Wales towards the close of the Lower Palaeozoic the deeper region of the Armorican geosyncline may have begun to rise while sedimentation was proceeding without much, if any, interruption on its northern flank. In such an event the products of denudation of the rising area would be swept forward to that flank to supply the final cover which buried to a great depth the coals of the coalfields.

It is unnecessary to point out that the courses of the isovols on an isovol map, with their maxima and minima and the varying distances between neighbouring isovols, resemble so much a series of structural contours drawn in a stratum affected by pitching folds that it is difficult to resist the impression that their distribution is in some way due to the post-Carboniferous earth movements which affected the field. One almost inevitably thinks of the minima as synclinal troughs and the maxima as anticlines. This impression is, however, false; the isovols represent merely the distribution of the varying volatile contents of a given seam and according to the depth of burial theory this distribution is the same as when the seam lay in the earth at the end of the Coal Measures, before the onset of the Armorican earth movements which gave the field its existing structures of anticlines and synclines and various kinds of faults. The isobaths record the approximate amount of depression at various points of the Nine-Foot seam during the formation of the particular portion of the Armorican geosyncline now occupied by what remains after denudation of a much larger South Wales coalfield; the troughs and ridges in the isobaths correspond therefore to maximum and minimum areas of depression.

Lines of progressive devolatilization must trend at right angles to the isovols and should therefore point towards these axes of isovol minima. Comparison of Dr. Trotter's fig. 1 with his isovol map, Text-fig. 8, demonstrates what a gross caricature of the facts is represented by the former figure in which the above lines are drawn as if they converged on the outcrop of the Careg Cennen Disturbance.

If, for the sake of argument, we assume that the original maximum cover over the Nine-Foot seam was 17,000 feet measured as fully compacted rock, the depth of the original column of mud and sand of varying degrees of compaction may well have been 20,000 feet. On any reasonable assumption regarding the temperature gradient during

the period of accumulation and the immediately following period when the geo-isotherms were rising throughout the geosyncline, it is difficult to suppose that the temperature of that seam could ever have exceeded 250° C.

According to some authorities anthracite can only be produced by a rise of temperature to over 500° C. This belief depends, however, on laboratory tests and it is almost certain that in the course of a long period of time comparable changes would be brought about at much lower temperatures. The history of the coals of the South Wales Coalfield seems to furnish conclusive evidence that this must indeed be the case.

Experimental researches (Cannon, etc., 1948) on various types of coal have recently shown that in bituminous coals there is a slight loss of volatiles between 100° and 200° although the main discharge occurs at about 400°, and it is clear that the curve of loss of volatiles against temperature has a perceptible slope at 100°. Even a slope of one-thousandth part of this would be ample to bring about in a long period of time the devolatilization noted in the various seam samples. The diagrams are too coarse to determine whether any comparable change occurs in anthracite.

Acknowledgment

I wish to acknowledge the assistance received from H. G. Dines of the Geological Survey in connection with the data from the Dover Coalfield. The Geological Survey have in the past supplied these figures to others, and there appear to be minor variations among them.

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Geology of the Aust-Beachley District, Gloucestershire

By W. F. WHITTARD

(PLATES XX–XXII)

ABSTRACT

The folds and many of the faults in the Keuper Marls of the Aust-Beachley District are claimed to be compaction phenomena. The distribution of almost vertical sheets of alabaster in the Keuper Marls is attributed to infilling of contraction cracks. The palaeontology of the Carboniferous rocks, particularly of the seldom-visited islands of the Severn, is used to determine the structure. Several post-Triassic faults of tectonic origin have been mapped and others predicted ; the age of the faulting is unknown.

INTRODUCTION

THE Roman city of Glevum, of which the City of Gloucester is the modern descendant, was sited alongside the lowest fordable crossing of the River Severn. The Severn Estuary commences below this position and shows so rapid an increase in breadth that throughout the ages it has constituted a major obstacle to land traffic. Even to-day no road crosses the estuary, the only communications between either bank being by the Severn Railway Tunnel, the Sharpness Railway Bridge, and the Aust–Beachley Ferry.[1] The ferry plies where the river attains the maximum range of spring tides of 41 feet [2] ; the flow of road traffic may be retarded by the ferry and, owing either to a low or to an exceptionally high tide or to limited berth facilities, motorists occasionally have to make a detour of approximately 55 miles via Gloucester in order to travel between South Wales and the southern and south-western counties of England. A road-crossing of the river at the most convenient position, namely between Beachley and Aust, is claimed by many to be a national need.

The first plan envisaged two road tunnels each carrying a one-way stream of traffic. Adequate information of the geology of the area, however, was not available, particularly of the five islands lying offshore from Aust Rock which are exposed only at low tide ; the most recent data relating to the rocks between English Stones and Oldbury Sands are contained in two confidential reports, of which

[1] The limits of the estuary are difficult to define but the pilotage areas for the Bristol Channel and the Severn Estuary are considered navigationally to join at King Road, Avonmouth. Physiographically the argument could be made that the estuary extends from Gloucester as far as a line drawn from Morte Point to Worms Head, a distance of 117 miles as measured along the river.

[2] Bassindale, R., 1943. Studies on the Biology of the Bristol Channel. XI. The Physical Environment and Intertidal Fauna of the Southern Shores of the Bristol Channel and Severn Estuary. *Journ. Ecology*, xxxi, pp. 6 and 7.

a condensed account was published in 1933.[1] A geological map on the scale of 25 inches to one mile was therefore made with a view to determining the geological difficulties likely to be encountered in tunnelling. For reasons mainly non-geological, an alternative plan was formulated for a suspension bridge carrying a central span of 3,300 feet; the geological problems under this new scheme are associated with foundation rocks, and a programme of borehole drilling has now been completed.[2]

Acknowledgment is rendered to Dr. Stanley Smith, who named the fossils collected from the Carboniferous Limestone. I also acknowledge a grant towards the cost of publication of this paper received from the Colston Society.

The Mesozoic Rocks

The classical section of Triassic-Rhaetic-Liassic strata of Aust Cliff has been the subject of several authoritative accounts, the first of which was written in 1824 by Buckland and Conybeare [3] and the last in 1946 by Reynolds,[4] but some of the familiar structures are re-interpreted here, and new information is made available.

The dominant structure is a gentle anticline crossing the cliff 200 feet north-east of Aust Head (Plate XX, A). To the south the strata are traversed by several faults all of which possess a downthrow never exceeding 20 feet away from the anticlinal axis. To the north-east three subsidiary synclines and two additional anticlines possess amplitudes of from 3 to 4½ feet measured at the base of the cliff, but they are supratenuous folds dying out upwards; no more than one fault is visible and this downthrows westwards. The folding and faulting have been tacitly attributed to tectonics but they can more readily be explained by compaction of the Keuper Marls. The Carboniferous Limestone forms an almost flat-topped ridge at Aust Rock, plunging steeply to north and south, and over which the Triassic beds unconformably rest. The ridge was succeeded above by a less thickness of deposits of Keuper age than was developed to the north and south, because in those directions the Triassic landscape occurred at a lower level and received a greater thickness of sediment. As a sequel to compaction there would be less reduction in thickness above the ridge as compared with that above the flanks, and an anticlinal flexure would develop. The bending moment induced by the increasing amounts of thickness-reduction of the marls when traced

[1] Report Severn Barrage Committee. *H.M. Stationery Office Publication* No. 63–78–1, pp. 16–19, 1933.

[2] Whittard, W. F., 1948. Temporary Exposures and Borehole Records in the Bristol Area. I. Records of Boreholes sunk for the New Severn and Wye Bridges. *Proc. Bristol Nat. Soc.*, xxvii, pp. 311–328.

[3] *Trans. Geol. Soc.*, 2nd Ser., i, p. 304 (pl. 37), 1824.

[4] *Proc. Cotteswold Naturalists' F.C.*, xxix, pp. 29–39, 1946.

southwards away from the ridge is proposed as the cause of the small-scale faulting exhibited in the cliff. However, a difficulty arises when a date for the completion of most of the compaction is considered; if compaction had been almost fully effected before the Jurassic deposition occurred, the fact that the faults cut the Lias would seem to prove the attribution of faulting to a bending moment developed out of compaction to be incorrect. Neither the folds nor the faults have any effect on the underlying Carboniferous Limestone and they are clearly peculiar to the Keuper Marls; a tectonic explanation is thus improbable.

The planed off surface of the ridge of Carboniferous Limestone on Aust Rock is assumed to have been produced during Trias times, but the evenness is broken by a north-westerly directed valley now infilled by Dolomitic Conglomerate and Keuper Marl (Plate XX, B). The complexity of the ancient land surface is also suggested by the logs of the boreholes sunk at the foot of and behind Aust Cliff which prove the surface of the Carboniferous to descend rapidly south-eastwards and possibly to occupy a continuation of the valley identified on the foreshore.[1] Carboniferous rocks reappear at Blackstone, north-east of Aust Rock, the intervening ground being occupied by Keuper Marls infilling a depression which faces the minor anticlines and synclines and the single fault already described from the north-eastern portion of the cliff section. These minor topographical irregularities of the Trias land surface may modify in detail the folding and faulting of the Mesozoic strata, but individually they are not considered to play an important role in determining the main structures in the cliff which, as already stated, are claimed to arise out of differential compaction, particularly of the Keuper Marls.

Another expression of the compaction which the marls have experienced is shown in the synclinal structures associated with infilled valleys, as developed on the foreshore between Beachley Point and the Hen and Chickens, and also at Aust Rock (Plate XX, B). The Trias unconformity can be accurately mapped in both areas and, without exception, the dips of the Dolomitic Conglomerate and the marls are away from the ancient land surfaces towards the valley bottoms. The curving strike in the Trias strata is sympathetic with the sinuous form of the unconformity and the valley infillings show a synclinal structure, which is evidently not due to tectonics. Greater sedimentation in the valleys than on their flanks would produce greater compaction and a synclinal form would emerge, although this may have been initiated by a depositional inclination. The large-scale map (Text-fig. 1) of Beachley Point exhibits the swinging strike, the variable

[1] Whittard, W. F., op. cit., p. 315.

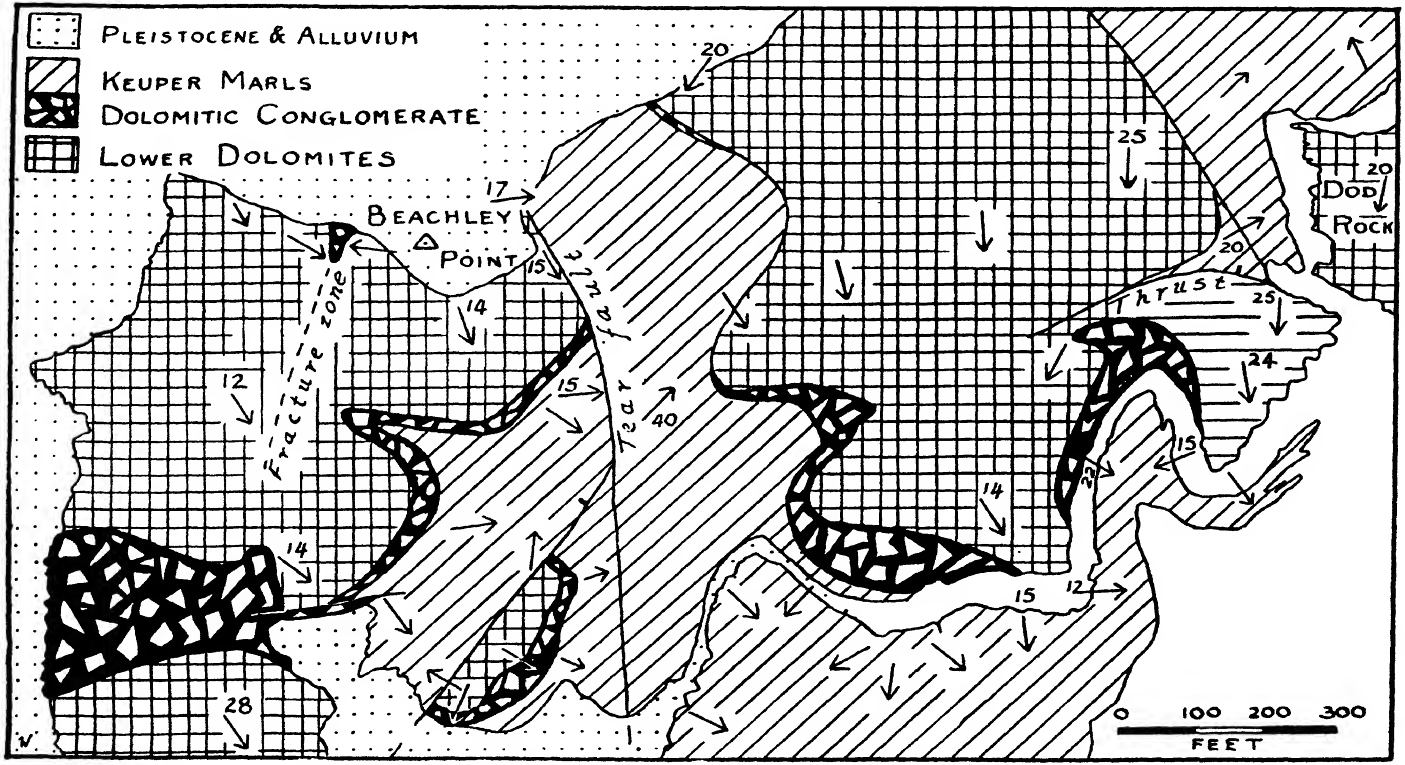
direction of dip, the high angles of dip relative to that prevailing generally in the Keuper Marls and the synclinal structures ; similar information, but with less detail, is shown on the smaller scale map of Aust Rock and of the country immediately north of Beachley Pier (Plate XXII).

A zone of gypsiferous marl is exposed in the cliff on both sides of Aust Head, but particularly on the south side, and is developed towards the base of the Keuper Marls. The gypsum occurs in the form of alabaster and satin spar, the latter being considered as secondary in origin. A typical section (Plate XXI, A) of the gypsiferous zone is appended.

	ft.	*in.*
(*g*) Red marls		
(*f*) Satin spar	0	1
(*e*) Red marls with curvilinear vertical sheets of alabaster and horizontally disposed wisps of satin spar . . .	7	0
(*d*) Red marls with thin layers and wisps of satin spar, and towards the base a concentration of nodular alabaster accompanied by stringers of satin spar . . .	3	0
(*c*) Red marls with curvilinear vertical sheets of alabaster and horizontal wisps of satin spar	3	0
(*b*) Nodular alabaster and satin spar included in red marls .	4	0
(*a*) Red marls		

No example was seen where a vertical sheet of alabaster of the lower bed *c* transgressed the intervening bed *d* to the upper bed *e*, although veins of satin spar occasionally do so. The sheets of alabaster, so common in beds *c* and *e*, possess a significant distribution. At first sight they appear to occupy random directions, but when plotted there are five or six predominant trends, and obviously the alabaster occupies fissures which fundamentally are polygonal in design, but with curved sides ; this arrangement can occasionally be seen in plan (Plate XXI, B). The two beds of marl containing the sheets of alabaster exhibit the features of contraction cracks occasioned by the partial drying out of mud, much as cracks are induced in the modern sun-dried muds of the Severn Estuary. The sheets are not infrequently discontinuous, a condition to be expected where cracks had coalesced or had become infilled with mud before the saline waters which flooded them were sufficiently concentrated to deposit the alabaster.

Specimens of so-called salt pseudomorphs are distributed throughout the shingle at Aust Head and are sometimes found in place at that locality and at the north-eastern end of Aust Cliff, but the term is a misnomer. Apart from the mineralogical difficulties of chemically replacing rock salt by micaceous marl and siltstone, wherever found in place in the field the " pseudomorphs " always occur on the underside of the siltstone and are the casts of moulds of salt crystals. The development by solution of the moulds may have occurred before the succeeding sediment was deposited, but solution could also have



TEXT-FIG. 1.—Intertidal outcrops from Beachley Point to Dod Rock.

(*Note.*—The area shaded with horizontal lines south-west of Dod Rock and south of the thrust should be shaded with crossed lines indicating Lower Dolomites.)

happened when sedimentation was in progress. The crystallization of the salt ensued when most of the mother liquor was evaporated, and the additional evidence of contraction cracks in the marls also indicates that the waters in which the marls were laid down retreated and permitted the development of land surfaces, if only for short intervals of time.

The Carboniferous Rocks

At Chepstow the Geological Survey has determined the succession of which that portion given below is pertinent to the Aust–Beachley district :—

Carboniferous Limestone (lower part only)	Lower Dolomites (Z-C_1 zones) . .		320 feet
	Lower Limestone Shales (K zone)	Shales with thin Limestones .	160 feet
		Lower Limestone	50 feet

In the Aust–Beachley district the Lower Limestone comprises dolomitic, platy limestones, red, yellow, or grey in colour, and occasionally interbedded thin, calcareous, greyish-mauve shales. The shales with thin limestones have not been recognized at the surface anywhere in the area but have been proved in bore-holes on the foreshore at Beachley. The Lower Dolomites are fine-grained, compact, tough, dolomitic limestones, often grey in colour but maroon and dark grey beds commonly occur.

The stratigraphical and palaeontological details are best considered by taking the isolated Carboniferous outcrops, commencing with Blackstone at the northern end of the Aust section.

Blackstone.

The western end of Blackstone alone could be reached, but here thin-bedded, closely jointed, mineralized, yellowish-brown and red, dolomitized limestones are interbedded with thin, calcareous, greyish-mauve shales. The fauna contains *Schellwienella* sp., *Camarotoechia mitcheldeanensis* Vaughan, *Syringothyris* cf. *cuspidata* (Martin), *Protoschizodus* sp., *Myalina* sp., *Edmonsia* sp., and dwarf gastropods ; it is an unusual assemblage but the rocks certainly belong to the K zone, and the abundance of lamellibranchs and gastropods at once suggests a correlation with the Lower Limestone.

Aust Rock.

The weed-covered surface of the ground, exposed about half ebb, is gently inclined south-westwards, and is an erosion platform of Trias age. Small outliers of Dolomitic Conglomerate rest upon it. The

Trias-filled north-westerly trending valley has already been mentioned (p. 367); the steep west side of the platform is flanked by Dolomitic Conglomerate inclined at angles up to 18°, and between Little Ulverstone and Aust Rock there is a Trias valley which to-day contains a remnant of Trias strata.

The majority of the surface of Aust Rock is composed of limestones providing numerous, yellow-stained, crinoid ossicles. The best collecting localities are in the spur facing Little Ulverstone; the fauna correlates with the Lower Dolomites and includes *Zaphrentis omaliusi* E. & H., *Koninckophyllum praecursor* Howell, *Rhipidomella michelini* (l'Eveille), *Plichochonetes* cf. *hardrensis* (Phillips), *Schellwienella crenistria* (Phillips), *Leptaena analoga* (Phillips), *Spirifer tornacensis* de Koninck, and ? *Tylothyris laminosa* (McCoy).

Selecting an average dip of 20° and assuming no repetition by strike faulting, 450 feet of Lower Dolomites are exposed on Aust Rock. This figure is a third more than the total thickness for the Lower Dolomites at Chepstow; furthermore, zones of brecciation trending approximately parallel to the strike can be detected and the limestones are extensively jointed. It is also significant that a fauna with *Koninckophyllum praecursor* was collected near the north-west point of Aust Rock; this coral is suggestive of a C_1 rather than a Z_2 age, but the stratigraphical position of the rocks would be Z_2 if the succession were normal. The outcrop of the Lower Dolomites is claimed to be complicated by strike faults of unknown extent resulting in an excessive thickness of outcrop.

Little Ulverstone.

The eastern and south-western edge of the island is flanked by coarse-grained Dolomitic Conglomerate, and at low water of the spring tide the saddle between the island and Aust Rock is seen to be made of a similar rock. A Trias valley was developed between Little Ulverstone and Aust Rock, and there is evidence to claim another such valley between Little and Great Ulverstone.

Grey, yellow-speckled, dolomitic limestone constitutes most of the island. The fauna points to a correlation with the Lower Dolomites (possibly Z_2) and includes *Phillipsia scabra* Woodward, *Zaphrentis* (*Zaphrentoides*) *konincki* E. & H., *Rhipidomella michelini*, *Plichochonetes* cf. *hardrensis*, *Leptaena analoga*, *Schellwienella* cf. *crenistria*, *Productus* (*Pustula*) *subpustulosus* Thomas, *Productus* ? *vaughani* Muir-Wood, *Cleiothyridina* cf. *glabristria* (Phillips), *Spirifer tornacensis*, and *Tylothyris laminosa*. The *Koninckophyllum* fauna from Aust Rock was collected from what appeared to be the same bed on Little Ulverstone, but that from Aust Rock proved to be much the younger; a fault is postulated between the island and the mainland and the

Trias valley which passes between them may have been eroded along this fault plane.

Great Ulverstone.

Apart from the Dolomitic Conglomerate which bounds the eastern margin, grey and pink, crinoidal, dolomitic limestone comprises most of the island. Few fossils were discovered but a recent borehole has produced a fauna suggesting a Z_2 age; the rocks are to be placed in the Lower Dolomites.[1] The limestones are crossed by a north-westerly trending fracture zone, of which there is a difference of 35° in dip direction between the two sides.

Leary Rock.

The island, which consists of red, yellow and grey, platy, crinoidal, dolomitic limestones, is divided longitudinally at half ebb and the two portions may be separated by a fault zone; the state of the tide was such that this could not be proved, but there is a difference in dip direction on the two sides. The meagre fauna contains *Plichochonetes* cf. *hardrensis*, *Schelwienella* cf. *crenistria*, *Camarotoechia mitcheldeanensis* and spiriferids, and the lithological types, including a red limestone charged with white crinoid ossicles and a bryozoa limestone, indicate the presence of the Lower Limestone (K zone). Assuming no repetition due to faulting and an average dip of 15°, approximately 65 feet of the Lower Limestone are exposed.

Upper Bench.

Dull pink, dolomitic, crinoidal limestones alone were seen in the short visit permitted by the tides. The rocks belong to the Lower Dolomites and the fauna is consistent with a C_1 rather than a Z_2 age, but reliable diagnostic fossils were not obtained. The fossils recovered included *Pleurodictyum* (*Michelinia*) *favosa* (Goldfuss), *Plichochonetes hardrensis*, *Schellwienella* sp., *Camarotoechia mitcheldeanensis*, *Cleiothyridina* cf. *glabristria*, *Spirifer tornacensis*, and *Tylothyris laminosa*.

Since Leary Rock is formed of the Lower Limestone (K zone) and the Upper Bench of the Lower Dolomites (C_1 zone ?), the shales and thin limestones which in the normal succession occupy an intermediate position, might be expected to occur in the river bed between the two islands. If an average dip of 15° be assumed there is room for a maximum of 200 feet of shales with thin limestone. This figure is probably excessive, it exceeds the 160 feet determined for these rocks at Chepstow, because the lowest beds of the Lower Dolomites have presumably to be included in that thickness. It may be concluded that apart from slight disturbances possibly in the shales with thin limestone the succession from Leary Rock to the Upper Bench is moderately

[1] Whittard, W. F., op. cit., p. 317, borehole 14.

straightforward. The existence of a trough between the islands is shown on Admiralty Charts and supports the view that the shales with thin limestones are developed and have been extensively eroded along their strike mainly by the ebb flow which is diverted by the Hen and Chickens across the river from the west bank.

Lower Bench.

The island, exposed for a short time only at low tide, consists of dolomitic limestones ; fossils are scanty but include *Syringopora* forma *distans* and *Koninckophyllum praecursor*, and indicate possibly a C_1 age.

There is a similar difference in the direction of dip between the rocks of the Upper and Lower Bench as prevails between the north and south parts of Great Ulverstone, and a continuation of the fault zone on the latter island may pass between the two islands.

North of Beachley Pier.

The Keuper Marls show several layers of sandstone and also contain numerous nodules of gypsum. The Dolomitic Conglomerate is massive and may carry angular limestone blocks attaining a length of 18 inches ; the outcrop is sinuous and, in a measure, reflects the distribution of the Carboniferous and Old Red Sandstone rocks to which it constitutes a discontinuous mantle.

The Carboniferous is represented in three inliers (inset, Plate XXII) in which the rocks exhibit considerable variation and include massive false-bedded green and pink sandstones, thinner-bedded greyish-white and pinkish-yellow sandstones, and crinoidal red limestones. The sparse fauna includes *Plichochonetes hardrensis*, *Camarotoechia mitcheldeanensis* and common fenestellids and points to a correlation with the Lower Limestone (K zone). The abundance of sandstones is suggestive of the lowest part of the Lower Limestone ; the strata may appertain to the passage beds between the Carboniferous and the Old Red Sandstone, and this view is supported by the close proximity of the Old Red Sandstone outcrops alongside the Lyde Light and at the Hen and Chickens. Here massive light grey, brown and green sandstones, brown conglomeratic sandstones with vein-quartz pebbles, and fissile highly micaceous brown sandstones are exposed and may be included in the Tintern Sandstone Group.

Beachley Point to Beachley Pier.

The rock-sequence on the Beachley foreshore is complicated by faulting affecting Carboniferous and Triassic strata (Text-fig. 1). The Lower Dolomites show their usual lithology and in the cliffs at the western end of Beachley Point and at about the level of high tide *Zaphrentis* (*Zaphrentoides*) *konincki*, *Z. omaliusi*, *Z. delanouei* E. & H., an early stage of *Michelinia*, and *Spirifer tornacensis* were obtained ;

Z. konincki is the commonest form and the assemblage is characteristically of Z_2 age. The Lower Limestone Shales do not crop out on the foreshore but the rocks have been proved in boreholes 5, 20, and 21 which were sited short distances south-west of Beachley Pier.[1]

Beachley Plateau.

The cliffs defining the Beachley promontory rise steeply to an almost level surface standing between 50–60 feet above Ordnance Datum. The surface of the plateau is occupied by Pleistocene sands and gravels which attain a maximum thickness of 23 feet as proved by boreholes. Trias rocks were penetrated below the Pleistocene veneer and in all cases the Lower Dolomites were reached. The only exposures of Lower Dolomites are in the vicinity of Ewen's Rock at the north-west corner of the plateau and *Zaphrentis* (*Zaphrentoides*) *konincki*, *Z. omaliusi*, and *Syringopora reticulata* Goldfuss are indicative of a Z_2 age.

Geological Structure

The faults and folds visible in the Mesozoic rocks of Aust Cliff have already been attributed mainly to non-tectonic causes, and the excessive thickness of Lower Dolomites on Aust Rock has been used as an argument for the development here of strike faulting of unknown extent.

The thicknesses of the subdivisions of the Carboniferous for the islands in the River Severn is inconsistent with and greatly in excess of the figures available for the Chepstow District, notwithstanding a reasonable allowance for variations in thickness between the two regions.

The distance between Blackstone and the nearest point on Aust Rock is such that a thickness of the order of 300 feet or 400 feet, according as an average dip of 15° or 20° be adopted, is required for the shales with thin limestones of the K zone. The thickness at Chepstow is unlikely to become doubled at Aust, and folding or strike faulting, probably the latter, may account for the apparent increase.

A south-south-east fault passing to the west of the Hen and Chickens has been mapped ; what is the likelihood of a fault with a comparable direction being developed on the east of the Hen and Chickens ? If the strike of the Lower Limestone of Leary Rock is continued towards the Old Red Sandstone of the Hen and Chickens, and soundings in the river suggest that an extension does occur, rocks of different ages would come into apposition. A sharp southerly curvature in strike is demanded in order that the Lower Limestone of Leary Rock succeeds normally the Old Red Sandstone. If this were the case, the dip of the Old Red Sandstone would almost certainly possess a southerly or a south-south-easterly direction, whereas it is inclined

[1] Whittard, W. F., op. cit., pp. 318–321.

consistently S. 35° W. A fault is thought to be present to the east of the Hen and Chickens, and may coalesce with the known fault immediately to the west, so as to run in a depression detected on the river bed, and to continue between the Lower and Upper Bench, where it would also account for the anomalous behaviour in the dip directions of those islands and for the increase in thickness in the Lower Dolomites which otherwise is developed there.

The deep trough in the river bed charted between the Upper and Lower Bench on one side and Great and Little Ulverstone on the other may have no tectonic significance. A minimum thickness of 410 feet for the Lower Dolomites can be calculated if the succession including Upper Bench and the northern part of Great Ulverstone as far south as the fracture zone traversing that island is considered simple; this thickness is in excess of the measurements made at Chepstow. A difference in direction of dip can be detected on Leary Rock and Blackstone, and in the absence of faulting a curving strike is required in order stratigraphically to connect the two islands. Some geological anomalies are thus associated with this trough, and the possibility that it is partly controlled by a zone of fracture should not be lightly dismissed.

The folding in the Keuper Marl on the foreshore at Beachley is attributed to compaction, but the faults are definitely tectonic in origin. The area has been affected by at least two different periods of movement, one earlier and the other later than the Trias.

Pre-Triassic movements are indicated by innumerable joints in the Lower Dolomites, many of which are now infilled with Dolomitic Conglomerate, and by a zone of brecciation trending north-north-eastwards and occurring 80 yards west-north-west of the Trigonometrical Station on Beachley Point; here, a small valley eroded along the zone of disturbance is also occupied by Dolomitic Conglomerate.

Post-Triassic movements are exemplified in the westerly-hading tear fault exposed to the east of Beachley Point where Lower Dolomites overlie Keuper Marls, in the thrust fault south-west of the Dod Rock where Lower Dolomites have advanced from the south-east over Trias and Carboniferous strata, in the vertical fault which trends south-eastwards to the Severn near Dod Rock and in the opposite direction probably joins the Beachley Point tear fault, and in the fault which parallels the shore from the Hen and Chickens north-westwards. The relationships of the Lower Limestone Shales (*vide* boreholes 5, 20, and 21) to the Lower Dolomites of the Old Limekiln and Dod Rock to the south, and to the Carboniferous and Old Red Sandstone north of the pier cannot yet be determined, because the mantle of Keuper Marls effectively obliterates most of the Palaeozoic rocks, but the succession is presumably abnormal.

Within the Aust–Beachley area the effects of tectonic movements of post-Triassic age, possibly posthumous in kind, are mainly confined to the Monmouthshire side of the Severn. Although a Miocene age might be claimed for them there is no evidence within the area which precisely dates the period of the movements. A pre-Upper Jurassic time is not altogether inadmissible; the presence of faults and the absence of tectonic folds is inconsistent with the magnitude of the load of superincumbent strata, which surely would have been involved if the movements were of Miocene date.

EXPLANATION OF PLATES

Plate XX

A.—Anticline, attributed to compaction, developed in the Keuper Marls 200 yards north-east of Aust Head. The photograph was taken from the Carboniferous Limestone platform at the south-east corner of Aust Rock looking south-south-east along the crest of the fold in the marls.

The foreground, as far as the isolated patch of shingle, is formed of Carboniferous Limestone, but the weed-covered rocks on either side and beyond this shingle belong to the Keuper Marls; they show anticlinal dips consistent with the anticline shown in the cliff.

The light zone near the top of the cliff indicates the Tea Green Marls, while at about one-third the distance up the cliff can be detected the gypsiferous marls containing nearly vertical sheets of alabaster.

B.—The platform of Aust Rock as seen to the north-west from the top of Aust Cliff. The Carboniferous Limestone, covered with sea-weed, shows a series of dip slopes inclined to the south-west which are crossed by joints. The north-westerly orientated Trias valley is indicated by the tongue of water of which the limits approximately coincide with the Trias-Carboniferous unconformity. The synclinal form and the swinging strike of the Trias are indicated by the sinuous ridges just emerged from the receding tide.

The patch of shingle at the bottom right hand half of the picture is the same as the patch referred to in the description of the previous photograph.

Plate XXI

A.—Gypsiferous beds exposed in the Keuper Marls 100 yards south of Aust Head (for details of succession see p. 368). *b* and *d* carry nodular alabaster, and *c* and *e* the nearly vertical sheets of alabaster which are claimed to occupy cracks formed in sun-dried muds. The sheets are variously disposed, the broad expanses indicating an orientation almost parallel with the plane of the photograph.

The white streaks are formed of satin spar.

B.—An oblique photograph of part of a nearly horizontal platform protruding from underneath bed *d*, and exposed about 50 yards south of previous locality. The polygonal pattern of the alabaster sheets is discernible.

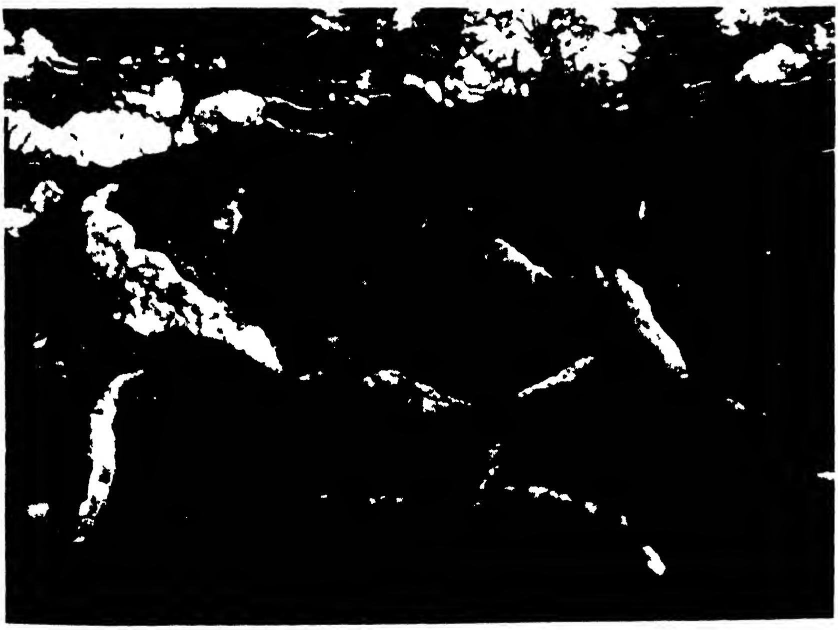
Plate XXII

Geological map of the Aust-Beachley area on the scale of 4 inches to 1 mile. A: anticline. S: syncline. The inset is a larger scale map of the area immediately north-west of the Hen and Chickens, and shows the three inliers of Lower Limestone. A larger scale map of the area south and east of Beachley Point is shown in Text-fig. 1.

A

B [E. B. Small photo.

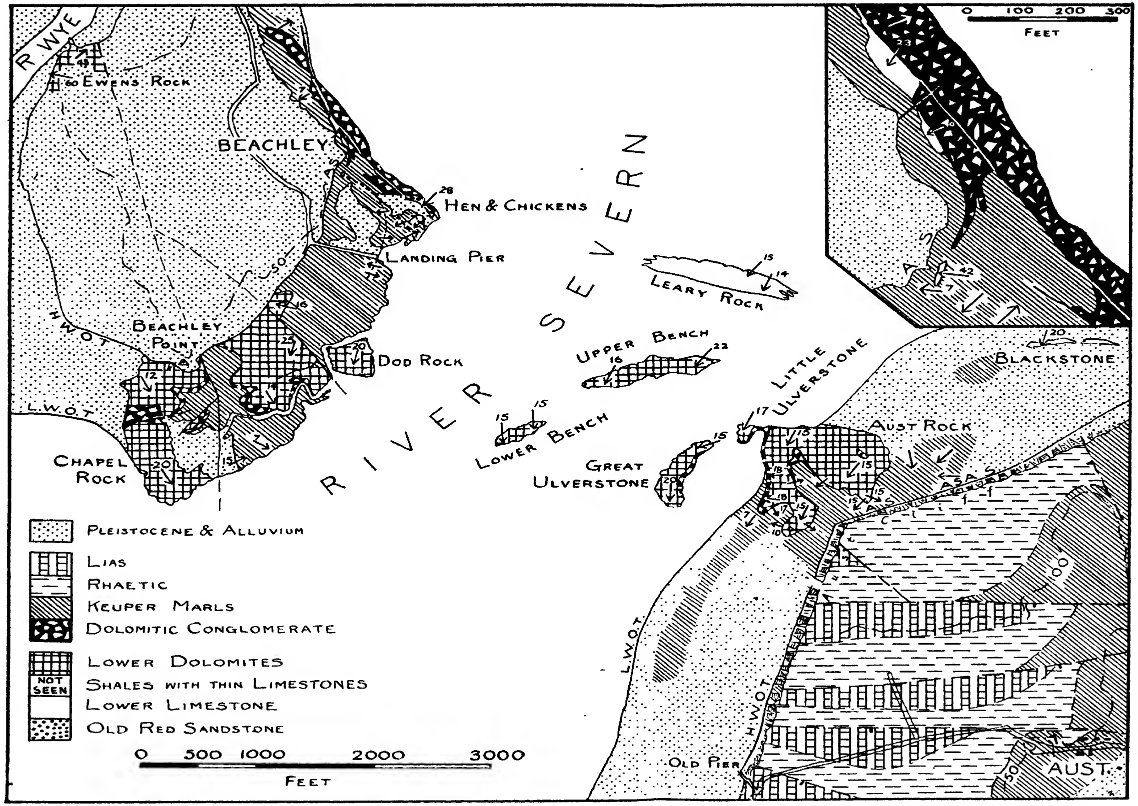
AUST ROCK AND CLIFF



[E. W. Seavill photo.

B

Keuper Marls of Aust Cliff.



GEOLOGICAL MAP OF THE AUST-BEACHLEY AREA, GLOUCESTERSHIRE.

The Lizard-Start Problem

By J. B. Scrivenor

Abstract

Two questions are discussed : what is the nature of the boundary between the Devonian rocks of the Meneage and of the Start area on the one hand, and the mica- and green schists to the south of them on the other ; and are the latter also Devonian or older than Devonian ? The author gives his views on the boundary in both cases, and concludes that the mica- and green schists in both are of Devonian age.

THE publication of the revised edition of the Geological Survey memoir on the Lizard and Meneage (1946), after a long delay owing to the war, affords an opportunity for reviewing the problem of the nature of the boundary between the Devonian rocks of the Meneage in Cornwall and of the Kingsbridge area in South Devon on the one hand, and the mica-schists with green schists south of the boundary in both areas on the other. It is generally agreed that the mica-schists in both areas are closely related, but two sharply conflicting views of their age have been expressed ; one that they are Devonian rocks more altered than those to the north ; the other that they are very much older than Devonian, perhaps Archaean. It is not necessary here to give a summary of all the previous literature on this subject as that has been done in the Geological Survey memoirs to the dates of publication (*supra*, and 1904 for the Kingsbridge and Salcombe country), but there are a few other publications to be mentioned. In Cornwall, Dr. Eileen M. Lind Hendriks has done much valuable work (1937 and 1939) including a discussion on the Start-Dodman-Lizard Boundary Zone. In 1923 Professor C. E. Tilley discussed the metamorphosed rocks of the Start area and in 1938 published a further paper on the green schists found there. It should be noted that the term " Start area " has been used for the South Devon promontory that extends from Bolt Tail to Start Point and contains the Salcombe Estuary. It has the advantage of brevity. In 1938 and 1939 five contributions to the geology of the Lizard were published by me. These appeared after the late Sir John Flett had written his revised memoir, but in 1938 I had the advantage of discussing both areas with Sir John, Dr. Hendriks, and Professor Tilley so fully that there is nothing in this paper that I have not communicated to them either verbally or in letters.

The Lizard

In the first edition of the memoir on the Lizard and Meneage (1912) the nature of the boundary between the crystalline rocks of the Lizard and those to the north was left an open question ; but in the revised version Sir John decided in favour of a faulted and thrust boundary and a pre-Cambrian or Archaean age for the Old Lizard Head Series

of mica-schists and associated green schists. He said : " The balance of evidence is entirely in favour of the pre-Cambrian or Archaean age of the sedimentary rocks of the Old Lizard Head Series and of the period of their metamorphism and of the intrusion of the Man of War gneiss. These rocks are part of a vanished land of crystalline schists and gneisses that in all probability had a considerable extension to the south and south-west. The crystalline schists of the Start in Devonshire and the gneiss of the Eddystone are probably members of the same series " (1946, map on p. 151, and text p. 118). My views on these points, namely that although dislocations occur on either coast of the Lizard, none has been proved to be a boundary-fault or boundary-thrust, and that the Old Lizard Head Series is Devonian metamorphosed in a different manner and degree compared with the Devonian beds on the north, have been sufficiently stressed already. I have nothing to alter in my published contributions.

Dr. Hendriks (1937), by unravelling the structure of a very complicated district to the north and north-east of the Lizard, rendered a signal service to those who for many years had been puzzled by the stratigraphy of South Cornwall. I have seen much of the ground she has described and appreciate the difficulties with which she had to contend. Her principal conclusions (1937) were that beds previously mapped as " Grampound ", " Ladock ", " Menaccan ", " Falmouth ", " Portscatho ", and part of those mapped as " Veryan " are really a continuous suite to be named " Gramscatho Beds " resting on Lower Devonian (Meadfoot) strata. The quartzites of Veryan with Ordovician fossils and fragments of limestone with Silurian fossils owe their position to thrusts with younger beds below them. The lateral movement which produced tectonic breccias was contemporaneous with an intrusion of serpentine like that of the Lizard and this intrusion and the pre-existing rocks can be correlated with the serpentines and hornblende-schists of the Variscan folds in the Lower Carboniferous province of central Europe. Her paper was accompanied by a map (pl. xxii) and sections (pl. xxiii). In the former, two lines representing crush-belts are shown crossing from the land north of Dodman Point to the Start area, the northern one with a query, the southern coinciding with the junction between the Devonian rocks of South Devon and the mica- and green schists. In one of the sections (pl. xxiii, fig. 3) the Lizard Boundary is shown as a " crush-belt (Great Thrust) ".

In 1939 Dr. C. J. Stubblefield published a paper on fossils that had been found within the limits of the 1 in. sheet 359 (Lizard and Meneage). He disagreed with the Silurian age attributed to black shales in Fletching's Cove and slate at Nare Cove, regarding them as Devonian. He also disagreed with the Ordovician age attributed to silt-stone at Mudgeon. He was unable to trace an *Orthis* found by J. H. Collins

in 1879, and said (op. cit., p. 64) : " despite repeated searches in the various quartzite outcrops of the Crush Zone and in the dry-stone walls of the neighbouring country there has been neither confirmation nor repetition of the earlier finds." An *Orthis* found at Mudgeon was re-determined as *Chonetes*, and the author concluded, after more fossils had been collected, that the rock was Lower Devonian. Other fossils found in black shale at Carn near Manaccan, were also regarded as Lower Devonian. This paper, however, did not deal with the fossils outside sheet 359 and mentioned by Dr. Hendriks (1937, pp. 332–4) as Ordovician and Silurian, except that a new genus *Corineorthis*, and species *C. decipiens*, are described from Perhaver, Goran Haven, the geological range being given as : " Probably Middle Ordovician, but horizon uncertain."

In the same year (1939) Dr. Hendriks discussed the nature of the boundary, being of the opinion that it is a zone rather than a line. She ascribed the inclusion of blocks of Ordovician and Silurian rocks in Devonian strata to nappe movements : " The boundary-zone is defined as a belt of variolite (ophiolite) " (spilite J.B.S.), " exotic blocks and serpentine intrusive in, and contemporaneous with, a great thrust. . . . The evidence appears sufficient basis for the suggestion that the Start–Dodman–Lizard boundary-zone may be a relic of a great Variscan nappe, associated with the fan-structure of Cornwall (loc. cit., p. 401)."

Before passing on to the Start area, remarks by Dr. Hendriks should be noted on the coarse conglomerate, known as the Menaver conglomerate, now considered not older than Middle Devonian (1937, Table 1, facing p. 350). Hill (1912, p. 200) described this rock and remarked on the absence of serpentine and gabbro fragments. In the revised memoir a complete list of fragments was given and the possibility of the rock being a volcanic agglomerate was mentioned (1946, p. 152). Dr. Hendriks (loc. cit., p. 346) says that the absence of serpentine agrees with evidence in Gerrans Bay and that the conglomerate is older than the 4d limestone of the Pendower Beach Beds (loc. cit., p. 345). This conglomerate at Nare Head is only one mile from the hornblende-gneiss and serpentine at Porthallow, so it is hard to understand why there are no fragments of them in it, if the latter is younger. My work at Porthallow, however, made me conclude that the hornblende-gneiss and serpentine are intrusive into the Devonian rocks and that that is the reason why no fragments of them have been found so far in the conglomerate.

The Start Area

In 1938 two visits to the Lizard and two to Torcross enabled me to compare the Lizard with the Start area. The geology of the latter is

not so complex. To the south of the boundary is an anticlinorium of mica-schists pitching west with two bands of green schists derived from igneous rocks converging on the west coast. North of the boundary are Devonian rocks ; as mapped it is almost a straight line from west to east, unlike the complicated boundary line of the Lizard.

Two main questions have been discussed : are the mica- and green schists Devonian rocks more altered than those on the north of the boundary or older than Devonian ; and, what is the nature of the boundary, is it a fault, a thrust, both or neither ? The arguments were summarized by Ussher and Teall in the memoir (1904, pp. 42–5) and in Chapter V the nature of the boundary is discussed without any definite conclusion ; but earlier Ussher had written (1891, pp. 511 and 512) : " From these facts it seems evident that the chloritic series " (the green schists J.B.S.) " is nothing more than a Devonian volcanic group. The more evident crinkling of the mica-schists in contact with the chloritic group seems to be due to their comparative softness and greater fissility during the crumpling and contraction to which both were subjected. . . ." Somervail and Hunt thought the mica- and green schists were Devonian ; and Teall wrote (1904, p. 45) in support of Hunt's evidence (1891, 1892) : " It may perhaps be as well to state here that the work of the Survey has tended still further to emphasize this point " (petrological similarity J.B.S.) " . . . Whatever the age of the rocks in the metamorphic area may be, it is practically certain that they represent a series of arenaceous and argillaceous deposits with which a considerable amount of basic igneous material was associated, and that, as far as original composition is concerned, they can be matched by rocks occurring in the Devonian area though the igneous and sedimentary types do not occur in the same relative proportions."

Tilley, however, said (1923, p. 193) : " The boundary line represents a plane of major dislocation bringing together rocks of different origin and markedly different grades of metamorphism." Of Hunt he said (op. cit., p. 191) : " The views of Hunt with regard to analogies in mineral composition between Devonian rocks and members of the Start schists are scarcely cogent evidence for the correlation of these two groups of sediments." Nevertheless, similarities of a petrological and mineralogical nature are frequently used as a basis for correlation when palaeontological evidence is wanting.

In addition to field-work I was able through the courtesy of the Director of the Geological Survey to borrow a number of rock-sections for examination. Regarding this question of mineral similarity, Hunt (1891) made a point of tourmaline occurring in both series of rocks. No one questions that ; but tourmaline is so widespread and persistent a mineral that it cannot be regarded under ordinary circumstances as

a guide to comparative age. In this case, however, there is something to be said for Hunt, because tourmaline, apparently all of detrital origin, is commoner than usual in some specimens of both series of rocks. The following are notes on slides in the Survey collection :—

North of the Boundary.

3081. Grit, cliffs south of Strete (east coast). Tourmaline occurs and there is a good deal of muscovite.
3083. Grit, Beacon Point (west coast), north of Outer Hope. Quartz, muscovite, a little calcite, possibly epidote, and several grains of tourmaline.
3095. Same locality as 3083. Tourmaline common.
3120. Siliceous grit, Mayson, Beeson. Several grains of tourmaline.
3079. Gritty shale, Tinsey Head (east coast, near the boundary). Much tourmaline.
3124. Mica-schist, Tinsey Head. Though labelled mica-schist it is not a good example, but there is quite a lot of muscovite visible in the slide. A few grains of tourmaline.

South of the Boundary.

1780. Quartz-schist, Start Point. Much tourmaline. This slide is mentioned on p. 48 of the memoir.
3113. Mica-schist, Start Point. Tourmaline occurs.
3116. Mica-schist, south of Bickerton Valley. Tourmaline occurs.

Tilley (1923, p. 179) mentions tourmaline as an accessory mineral of the mica-schists, with titanite, iron-ores, epidote, zircon, rutile, apatite, and ilmenite.

On p. 48 of the memoir Hunt is quoted as saying, in connection with quartz-schists south of Start Farm : " . . . the quartz-schist bands containing tourmaline have much resemblance to the grit bands in the slates, both in relation to the mica-schists and in their fineness of grain. If there is no connection between the two sets of rocks, the conditions of sedimentation at the deposition of the schists must have been exactly repeated in Devonian times." The presence of titanite (sphene) as an accessory in the mica-schists is interesting. It is less stable than tourmaline, and if it could be proved to be present in the undoubted Devonian sedimentary rocks as well it would be better evidence for correlation than the tourmaline. I cannot find any mention of it. A systematic examination of the heavy minerals in both groups of rocks might give valuable information. At present Hunt's stress on the importance of the tourmaline is not so impressive as other evidence. My visits to Torcross enabled me to examine the coast-sections up to Start Point thoroughly, with the result that the mica-schists appeared to me to be the Devonian rocks subjected to a greater degree of dynamic metamorphism, and the rocks at Tinsey Head appeared to be a transitional type (see note on slide 3124 above).

On the west coast, at Mouthwell Beach, the dip of the slates is very steep to the north, but the mica-schists and green schists on the Inner Hope Beach dip south. In between is Hope Headland where the slates

have been badly disturbed, but a steep northerly dip can be seen. The mica- and green schists are obviously much sheared, as though thrust from the south. On Mouthwell Beach at low tide a strip of sand was seen running seaward between low walls of Devonian rocks. At the head of the beach weathered black slate and yellow rock were exposed. No fault-breccia was visible but it looked as though the sea had cut in along a weak band, possibly caused by a fault. On the north the Devonian rocks resemble those of Tinsey Head. On the south they are more like mica-schists and more disturbed. In the Inner Hope cliff-section, which is shown in the frontispiece of the memoir, I thought that the green schists resembled the sheared igneous rocks at Dun Point ("Limpet Rocks" on the 1 in. map), at Torcross. The latter are described in the memoir by Teall (1904, p. 28) as a probably modified diabase consisting of carbonates, chlorite, scales that are perhaps white mica, quartz, and felspar. That they are a northerly extension of the green schists associated with the mica-schists does not admit of much doubt. The green schists of Inner Hope are described by Teall in the memoir, on pp. 60 and 61.

Inland I was unfortunate in not being able to examine the Southpool Creek section closely, but Ussher gives a drawing of it (1904, p. 55, fig. 23). This shows Devonian slates separated from " Brown Rocks " and green schists by a thrust from the *north*, not south, described in the text as a thrust with a northerly inclination of 45°. Tilley (1923, pp. 191, 192) says of this section that it is one of the best for evidence of a dislocated junction, and that the junction is marked by an ironstone band hading northwards.

The boundary on the east coast is shown on the 1 in. map at Greenstraight. It is figured by Ussher (1904, p. 53, fig. 22) and again he shows a thrust from the north. The text shows that he was doubtful about this being the boundary. When I saw the section in 1908 it was so weathered that it did not afford much information. Tilley (1923, p. 177) said that he regarded the green schists mapped here as Devonian rocks, and that the actual junction seemed to be hidden in the valley. This valley makes the coast section, at the critical point, more unsatisfactory than that on the west. It does not help to elucidate the question of what the boundary is, a great thrust, or a fault and if so whether a normal or reversed fault, or is it a band along which there have been dislocations involving faults and thrusts ? There does not seem to be any evidence for a great thrust in the sense of a force that caused the mica- and green schists to override the Devonian rocks ; but the high north and south dips suggest lateral pressure resulting in folding, shearing, faults, and thrusts with dynamic metamorphism greatest on the south because that was the direction from which most pressure came. If the boundary is a single normal fault hading south

it would mean that more metamorphosed rocks had originally been above the Devonian beds ; if reversed, it would suggest that Devonian rocks in depth were more metamorphosed and had, along this line, been pushed up, which is understandable.

Tilley described the green schists as mainly chlorite-epidote-albite and hornblende-epidote-albite schists with a very small amount of quartz, all derived from igneous rocks. Nodular masses occur consisting mainly of epidote with chlorite, albite, hornblende, and, at Hamstone Cove, quartz (1923, p. 181). He wrote (op. cit., p. 200) : " The mica-schists of the Old Lizard Head Series bear comparison with the Start mica-schists, while the hornblende-schists considered by Dr. J. S. Flett as originally lavas and sills are chemically identical with the green schists." The hornblende-schists referred to are Flett's Landewednack type, called by E. H. Davison (1930) and myself, gneiss, not of metamorphic origin. The analysis given by Tilley of a specimen of Start green schist (op. cit., p. 183) is remarkably like that given by Flett of the Lizard rock (1912, p. 48), but the two rocks differ in mineral constitution and origin. On the other hand, the green schists in the Old Lizard Head Series are distinct from the Landewednack hornblende-schist (Scrivenor, 1938, p. 518) and resemble the Start green schists, but albite has not been proved so far and quartz is more abundant. Tilley (1937, p. 307) mentioned acid plagioclase in granulites at Pistil Ogo. It seems reasonable, without proof of close mineral resemblance, to regard the Lizard green schists as of the same age and origin as the Start green schists, i.e. derived from igneous rocks contemporaneous with and perhaps intrusive into the mica-schists of both areas.

The mica-schists of the Lizard differ from those of the Start in that they show evidence in the neighbourhood of Lizard Head of thermal metamorphism which has not yet been detected in the Start mica-schists. At Lizard Head this has been ascribed to the Man of War Gneiss (Flett, *supra*, 1946, p. 118) exposed in the islets off the coast. This leads to consideration of what we know about the bed of this part of the English Channel.

Hunt (1880–5, with notes by E. B. Tawney and T. G. Bonney) gave valuable information on this subject. The following rocks were recorded as having been collected in trawls : gabbro with killas attached ; actinolite rock ; diabase ; flints ; granite from a ledge twenty miles south-west of Eddystone ; gneiss and red granite of Eddystone. Hunt said that there is a large tract of the sea-bottom off the south coast of Devon where blocks of rock abound, and added that they could be roughly grouped into granites, gneisses, syenitic rocks, serpentine, diorite, diabase, gabbro, and conglomeratic grit (1881, p. 168). Tawney and Bonney described specimens in some

detail, including three from the Eddystone Rock. The granite-ledge is about twenty-five miles due south from a point on the coast of Cornwall four miles east of Fowey. Gabbro and actinolite rock were trawled about sixteen miles due south of Start Point. How far the rocks other than those from the ledge and from Eddystone can be regarded as *in situ* is not known ; but the information Hunt gave affords reason for believing that a considerable area of granite, gneiss, etc., exists on the sea-bottom in this part of the English Channel. The gneiss indicates pressure, so it may be that the crust here was subjected to a higher degree of disturbance than the crust farther north during Armorican movements, resulting in a higher grade of dynamic metamorphism seen in the Lizard and Start schists.

Summary

The Nature of the Boundary

Beginning in the west, the fault on Polurrian Beach was very clear in 1936 hading S.E. 45°, but later it was covered by a fall from the cliff. On the 1 in. map it is marked too far to the south as though cutting the Polurrian Hotel. Its real postion is consistent with being in the valley north of the hotel. If produced seaward it would pass north of Mullion Island with its pillow-lavas and radiolarian cherts, which is not consistent with its being a Lizard boundary-fault. Inland it has been mapped as ending in the Lizard group. On p. 206 of the 1912 memoir is the following : " Moreover, the very fact of its entering the Lizard group shows that it is only of local importance." In 1936 this was one of the clearest faults in the Lizard or the Start. In the former there are two other clear faults separating serpentine from older rocks, one on Pentreath Beach, near Lizard Town, where it hades N.N.E. ; the other at the Balk, hading N.W. In Housel Cove there is a clear fault hading N.E. 45°, and an equally clear thrust, hading N.W. 5° in hornblende-gneiss, that forms a platform in the cliffs.

At Porthallow shearing is very strong. The boundary fault as mapped goes off into the killas but I was unable to trace it inland. The geology of Porthallow was discussed thoroughly in my fifth paper (1938). Dr. Hendriks has published a clear section of the coast up to Nare Point (1937, pl. xxiii, fig. 3), but I cannot agree with her " Lizard Boundary crush belt (Great Thrust) " at Porthallow because killas occurs on either side of it and there are thrusts along the coast to the north that are no less great. They all hade southward. In the section from Loe Bar to Polurrian Cove all the dislocations except two are shown hading southward (loc. cit., fig. 4). Inland faults and thrusts forming a boundary are only conjectural though the sections on both coasts make one expect dislocations in the intervening country. This

absence of positive evidence applies to the rock-exposures at Gweleath, described in the revised memoir (1946, pp. 117, 118). The " Lizard Boundary " is really the northern limit of the large intrusions of hornblende-gneiss and serpentine.

For the Start area Ussher (1904, pp. 11, 12) gives a summary of schistosity-dips from Mouthwell, Salcombe, and Bickerton Valley (east coast) northwards. They are northerly, southerly, and vertical. I found that the prevalent dips on the east coast are northerly, even at Hallsands south of the boundary. At Start Point the prevalent dip is steep to the south. Unlike the country north of the Lizard there is no evidence here of a force causing shearing from the south only. There seems to have been a compression from the north and south and the supposed boundary between Devonian and older rocks is a line where the two forces met. There is no evidence of a great thrust from the south but the higher grade of metamorphism on the south is probably explained by the compression having been stronger from that direction. The brown rocks frequently mentioned in the memoir are the result of weathering of limestone lenticles, green schists, and perhaps sedimentary Devonian rocks also.

The Age of the Mica-schists

Unless recognizable organic remains are found, only very careful field-work can guide us to a solution of the question whether the mica-schists in both areas are Devonian or older. My field-work in 1936, 1937, and 1938 convinced me that they are Devonian (see 1938, pp. 101–5) as far as the Lizard is concerned. In the Start area the east-coast sections from Torcross to Start Point are to me equally convincing that there also the mica-schists are Devonian.

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CORRESPONDENCE

PHOTOGRAPHIC PRINTS FROM CELLULOSE-ACETATE TRANSPARENCIES

Sir,—The method of obtaining cellulose-acetate transparent moulds from etched surfaces has been previously described in detail (Walton, 1928; Leclercq, 1928) and is now a recognized palaeontological technique. In the case of corals or other organisms with calcium carbonate skeletons, the method does not replace the thin section, but it is a valuable substitute for it because of its speed and ease of preparation, the lack of any risk that the section will be lost in the last stages of preparation, and as a permanent record of serial sections which are progressively destroyed as they are made. One of the disadvantages of the "cellulose pull" is its lack of contrast and the difficulty of translation of its detail to a photographic print. Various techniques to overcome this have been described (Walton, 1928; Dollar, 1948), but I have not read of one which does not depend on pigment or staining to obtain the necessary contrast.

Working recently with cellulose transparencies of Carboniferous corals, I was able to produce direct enlargement prints from the "pulls" with strong contrast almost equal to that obtainable from a thin section. The process involved nothing more than an adaptable enlarger and the correct selection of paper, developer, and fixer. In view of the widespread use of cellulose pulls, it was suggested that the details of procedure might be published.

The use of grade IV gaslight paper in conjunction with an enlarger will normally be found to supply the desired contrast. The great disadvantage of gaslight paper used in this way is the length of time of the exposure, but a photoflood bulb in the enlarger will overcome this. The distance of the bulb from the condenser in the enlarger may have to be varied in order to obtain even illumination. Conveniently there are two normal sizes of photoflood bulbs—No. 1 with bayonet fitting, about the size of a 60 watt bulb and No. 2 with Edison screw fitting about the size of a 150 watt bulb. The length of time of exposure naturally will vary considerably depending

on which type of bulb is used and the peculiarities of each enlarger. Using a No. 2 photoflood and a lens aperture of f12, I find an average exposure to be in the region of ten seconds for an enlargement of 2 diameters. So far as possible ground glass plates in any position in the optical system of the enlarger should be dispensed with. They disperse the light and reduce the contrast.

Experiment has proved both Kodak and Ilford gaslight papers grade IV to be equally suitable. The Kodak paper, if anything, is a shade more contrasty. Glazing, if convenient, is well worth while. For development Kodak Special Developer D. 163 has given the best results, and if diluted 1 to 1 instead of 1 to 3 and used warm (100° F. or 38° C.) gives more contrast than many of the special contrast developers. The print " comes up " very quickly because of the temperature of the developer, but exposure can be regulated to give a two-minute development time. Fixing in double strength acid fixer clears the print still further due to the slight reducing effect of the hypo.

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SHEFFIELD UNIVERSITY.
11th October, 1949.

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BOREHOLE SECTIONS AT ROSENEATH AND ROW

SIR,—In his recent paper on " The Gareloch Re-Advance Moraine " (*Geol. Mag.*, lxxxv, 239–244), Dr. J. G. C. Anderson has discussed the interesting section of raised beach and moraine deposits seen in the cliff along the north-western side of Row Point, and has remarked on the absence of any similar evidence with regard to the internal structure of Roseneath Point. Some war-time borings, which provided sections on both sides of the loch entrance to 60–70 feet deeper than the base of the Row Point exposures, may now be placed on record.

During the construction of a military port, the Consulting Engineers to the scheme maintained the possibility, despite geological arguments to the contrary, that the Row and Roseneath spits might be based, at no great depth, on a solid rock bar ; in which case a considerable amount of blasting might be necessary to clear a channel adequate for vessels of 30 feet draught at all states of the tide. A detachment of 7 Boring Section, R.E., put down three holes, in July, 1941, to decide the matter. The holes were restricted to testing to a depth of 30 feet below low water mark, and all of them failed to reach solid rock within this limit.

The first hole was sited at high water mark on the outermost point of the Roseneath spit. After casing-off 8 feet of loose shingle the hole passed through 52 feet of thinly-bedded blue-grey clays and silts to its finishing depth of 60 feet. The second hole also was drilled from high water mark on the Roseneath spit, but to the south of the pier, and at about the same distance from it as No. 1. The section proved was practically identical with that of No. 1 : shingle, 8 feet ; blue-grey clays and silts, 53 feet. The third hole was drilled from a barge, which was grounded after manoeuvring into position at high tide, about ten yards south-east of the navigation beacon at the outer end of the Row spit. The section in this hole was : shingle, 26 feet ; soft blue-grey clays and silts 30 feet.

A channel to 30 feet below Chart Datum over a width of 400 feet was dredged subsequently at Row Point without encountering any solid rock. A large portion of the 150,000 cubic yards removed was "ballast", and was used for filling-in behind the 150-ton floating crane berth at Faslane Bay.

T. O. MORRIS.

35 BARKLEY ROAD,
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8th September, 1949.

REVIEWS

LANDSCAPE AS DEVELOPED BY THE PROCESSES OF NORMAL EROSION. By C. A. COTTON. 2nd edition, pp. 507, with 375 figures. Whitcombe and Tombs, Ltd., Christchurch, New Zealand. 1948.

The first edition of this book was published by the Cambridge University Press in 1941. This second edition has been a good deal enlarged and in part rewritten. A good many photographs have also been added and the whole has been printed and produced in New Zealand. Meanwhile, Professor Cotton has written three other books: *Geomorphology*, an introduction to the study of land forms; *Climatic Accidents in Landscape Making*, about arid regions and glaciation; *Volcanoes as Landscape Forms*, a title which explains itself. The last two and the present book form a trilogy, which covers the whole subject of landscape making so far as now developed. The one section of the subject which has not yet been worked out in detail is landscape in wet tropical climates, except by Sapper, in German, and by the American geologists in Hawaii.

Naturally the examples are chosen and most of the photographs are taken from New Zealand, which affords very fine specimens of nearly all the types of scenery attributed to what is generally known as normal landscape making—that is the action of water and rivers. As a matter of fact this is not really more normal than anything else, such as glaciation, aridity, and volcanoes, but it is much commoner, although it should be remembered that it is estimated that about one-fifth of the whole land surface of the earth is arid, much of it absolute desert and therefore not much seen.

The work of W. M. Davis is very largely quoted, and a great number of his diagrams are reproduced, either directly or redrawn. Occasionally in these the perspective has not quite come off, especially in meanders, and in a few instances one wonders whether Davis really saw anything like that or whether he invented the whole thing. The general impression given by most of the photographs in this as well as the other books, is that the scenery of New Zealand is very exaggerated, and most remarkably varied.

While it is perhaps permissible to express a little scepticism as to some of the Davisian diagrams, Professor Cotton is to be heartily congratulated on the general success of the book, which is about the best non-American work on the subject. It is eminently readable, and is suited both to the general reader and to the specialist.

R. H. R.

THE GEOLOGY OF WATER SUPPLY. By SIR CYRIL S. FOX. pp. x and 209, with 49 figures and xxiii photographs. The Technical Press, Ltd., 1949. Price 25*s*.

Sir Cyril Fox has a life's experience of the practical application of geology to everyday problems. This book is written to give some of that experience to others but, as he says in the Foreword: "books . . . cannot by mere reading, provide that information gained by actual experience." Throughout, the text points are illustrated from Sir Cyril's own experience or by quotations from that of others. Naturally, many of the examples are drawn from India.

Throughout, the book contains much in the way of tabulated facts and figures which it will be useful to have collected together in one book, but at times it is rather hard to see why some of them are included in a book on the geology of water supply. For instance, on page 51, under " Thermometer ", we have a selection of temperatures from that of the electric arc to absolute zero, and on page 206 there is a list of chemicals with their " common names " and chemical names and formulae.

The text is illustrated throughout by accounts of floods, storms, engineering enterprises, etc., but again, some appear to be hardly relevant, as for instance the story of the recovery of the *Laurentic's* gold by divers—given verbatim from the *Daily Mail's* account of the proceedings.

Since so much has been published in the official memoirs and in books on water supply in the United States, it is strange to find practically no references to these works, and it may also be noted that very few of the papers quoted in the text date from the last twenty-five years.

There are some good photographs but the diagrams are, on the whole, poor.

W. B. R. K.

THE MIDDLE SILURIAN ROCKS OF NORTH WALES. By P. G. H. BOSWELL. pp. xvi + 448, with 25 plates and numerous text-figures. Edward Arnold and Co., 1949. Price 80*s*.

This book is the record of the vast amount of work which Professor Boswell has done on the Lower Palaeozoic rocks of the Denbighshire moors. As he says, he has been working in this area for over twenty-five years and naturally during that time has accumulated a wealth of detail and large collections of fossils.

The book is divided into two main but unequal parts: Pages 1–175 (Part I) deals with the general geological problems of the area as a whole, and in this geologists will find much of value and general application. After a general introduction, there is a chapter on Stratigraphy, in which there is an account of the general characteristics of the lithology and palaeontology of the successive zones with details of thicknesses, lithology, etc., in the various areas, and fairly full lists of fossils. In fact, these 35 pages give an admirable and full summary of the 258 pages of Part II. Details of structure follow with critical studies of fault and joint patterns, and of the cleavage fan which is claimed to be present. A map indicating the extremely irregular distribution of cleavage strength shows how complex the cleavage problem is in this district. The presence of a " cleavage sanctuary " near the Carboniferous boundary tends to lessen the value of the implications drawn from the presence of uncleaved Silurian rocks in the Carboniferous conglomerates. The next pages deal with the interesting subject of Intraformational Disturbances—a subject which has given rise to considerable controversy. Professor Boswell discusses the characteristics of these beds, their condition at the time of disturbance, and the views which have been put forward to explain these and similar disturbed beds from other areas. As a result, Professor Boswell considers that disturbed beds may arise from various causes of which submarine sliding or slumping is but one. He tends to minimize the importance of these beds in the general succession. However, from this book it would appear that the matter in dispute is now more one of degree than anything else.

The first part of the book ends with chapters on the petrology and palaeontology. These bring out the monotonous character of the series, and appear to justify the mnemonic that the graptolite zones of the Ludlow contain " merely last traces, some nasty varieties ", a saying which even if not quite true does help one to remember the order in which the zones occur.

For these 175 pages all geologists will be grateful, but Part II runs from pages 176 to 434, and is headed " Details of the Areas ". Maps illustrate each area, but many are reprints of maps previously published in various

scientific journals. The minutely descriptive accounts may be of value to workers going into the area and anxious to find the best fossil localities and exposures. In these days when there is such difficulty in getting new work published even on a much reduced scale, one wonders if all this detail is justifiable.

W. B. R. K.

FEDERATION OF MALAYA : REPORT OF THE GEOLOGICAL SURVEY DEPARTMENT FOR THE YEAR 1948. By F. T. INGHAM, Director. pp. 59, with 2 maps and a Folding Chart. Government Press, Kuala Lumpur. 1949. Price $2 or 4*s*. 8*d*.

The work of the Geological Survey seems to have been more or less normal in 1948. One or two bits of field work are unfinished owing to bandit activity, and some of the time of the staff was taken up with organizing Special Constabulary. The work of the Chemical Department went on as usual, with two chemists for part of the year.

The principal items of work carried out were as follows : In West Central Pahang, by H. E. F. Savage ; near Kuala Lipis, by H. Service ; near Bentong, Pahang, by J. B. Alexander ; in North Selangor and Ulu Selangor, by F. W. Roe ; near Kuantan, Pahang, by F. H. Fitch ; in Southern Trengganu, by A. C. Amies. The Director accompanied Dr. F. Dixey to Borneo, Sarawak, etc. Some more fossils have been collected and identified in England. They are mostly Carboniferous.

R. H. R.

STRUCTURAL HISTORY OF THE EAST INDIES. By J. H. F. UMBGROVE. 63 pp., 68 text-figs., x plates. Crown quarto. Cambridge University Press. 1949. Price 30*s*.

Many who heard Professor Umbgrove deliver his six lectures in Cambridge in 1946 will be glad to learn that the substance of these is now published. In the preface it is clearly stated that little has been done to modify the original form of the contribution. The author therefore cannot be blamed for the disappointment which many will feel on realizing that the fine appearance of this book, with its comprehensive title, generous illustrations, and large page size, does not reveal a new and authoritative treatise on so important an area.

The six chapters are entitled The Shallow Seas, Deep-sea Basins and Troughs, Volcanoes, Structural Zones, Geophysics, and Synthesis. Throughout interest is not narrowly confined to structural history, and a discussion for instance on the distribution of Red Clay and Globigerina Ooze in modern deposits is thrown in for good measure. Geologists will find the main meat in Chapter IV, Structural Zones, in which the salient facts concerning Palaeozoic and Mesozoic history are outlined. With more evidence in the Tertiary four structural zones are distinguished by different stratigraphical histories.

As a series of lectures they are admirable, being easy to follow without the encumberance of detail which is shown diagrammatically. Professor Umbgrove has drawn on a rich source maps and diagrams in the prolific publications of this Dutch School. The spoken style with its ready admixture of fact and opinion, argument and prejudice, makes for rapid and stimulating reading. There is no encouragement, however, to think more deeply into the many interesting problems, as neither data nor references are adequately provided. One is therefore left with a feeling of remoteness from field geology which inevitably derives from summaries of summaries.

This is a valuable book outlining Professor Umbgrove's opinions from a host of publications, but an opportunity has been lost of publishing a study of more permanent value when such a fine production was materially possible.

W. B. H.

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